

# Proceedings



of the

I · R · E

**Journal of Communications and Electronic Engineering**

**February, 1952**

Volume 40

Number 2

**IRE**  
**NATIONAL CONVENTION**  
New York City

**RADIO ENGINEERING SHOW**  
Grand Central Palace

**IRE CONVENTION**  
Grand Central Palace—Waldorf-Astoria Hotel

**MARCH 3-6, 1952**

Convention Program and Summaries of Technical  
Papers appear on pages 212-234

## PROCEEDINGS OF THE I.R.E.

Admissions and Transfers  
Photograph Reproducer Arm Damping  
Retarding-Field Oscillators  
Improvements in Television Pickup Tubes  
Q of a Microwave Cavity  
Tachometer for Servomechanisms  
Portable Microwave Noise Generator  
A General-Purpose Electronic Wattmeter  
Distortion in Transmission Systems  
Dielectric Waveguide  
Short-Slot Hybrid Junction  
Measurement of Atmospheric Noise  
Influence of Core Material on Thermionic  
Emission  
Generalized Method for Analyzing  
Servomechanisms  
Gain Stability of the Superheterodyne Mixer  
Mutual Coupling of a Slot with a Dipole  
Antenna  
Abstracts and References

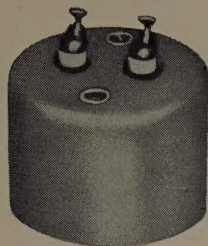
TABLE OF CONTENTS, INDICATED BY BLACK-AND-WHITE  
MARGIN, FOLLOWS PAGE 96A

# The Institute of Radio Engineers



## PERMALLOY DUST TOROIDS FOR MAXIMUM STABILITY...

The UTC type HQ permalloy dust toroids are ideal for all audio, carrier and supersonic applications. HQA coils have Q over 100 at 5,000 cycles...HQB coils, Q over 200 at 4,000 cycles...HQC coils, Q over 200 at 30 KC...HQD coils, Q over 200 at 60 KC...HQE (miniature) coils, Q over 120 at 10 KC. The toroid dust core provides very low hum pickup...excellent stability with voltage change...negligible inductance change with temperature, etc. Precision adjusted to 1% tolerance. Hermetically sealed.



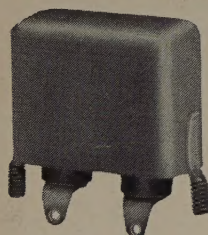
**HQA, HQC, HQD CASE**

1 13/16" Dia. x 1 3/16" High



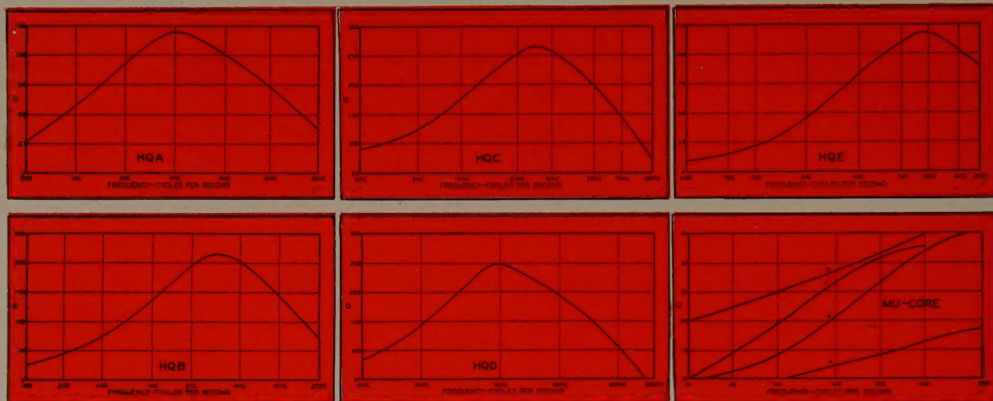
**HQB CASE**

1 5/8" x 2 5/8" x 2 1/2" High



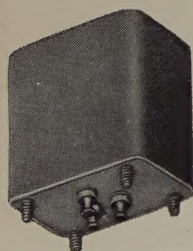
**HQE CASE**

1/2" x 1 5/16" x 1 3/16" High



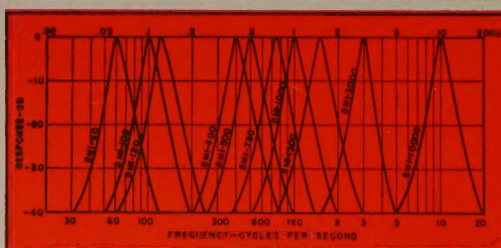
Type No.	Inductance Value	Net Price	Type No.	Inductance Value	Net Price	Type No.	Inductance Value	Net Price
HQA-1	5 mhy.	\$7.00	HQA-16	7.5 hy.	\$15.00	HQC-1	1 mhy.	\$13.00
HQA-2	12.5 mhy.	7.00	HQA-17	10. hy.	16.00	HQC-2	2.5 mhy.	13.00
HQA-3	20 mhy.	7.50	HQA-18	15. hy.	17.00	HQC-3	5 mhy.	13.00
HQA-4	30 mhy.	7.50	HQB-1	10 mhy.	16.00	HQC-4	10 mhy.	13.00
HQA-5	50 mhy.	8.00	HQB-2	30 mhy.	16.00	HQC-5	20 mhy.	13.00
HQA-6	80 mhy.	8.00	HQB-3	70 mhy.	16.00	HQD-1	.4 mhy.	15.00
HQA-7	125 mhy.	9.00	HQB-4	120 mhy.	17.00	HQD-2	1 mhy.	15.00
HQA-8	200 mhy.	9.00	HQB-5	.5 hy.	17.00	HQD-3	2.5 mhy.	15.00
HQA-9	300 mhy.	10.00	HQB-6	1. hy.	18.00	HQD-4	5 mhy.	15.00
HQA-10	.5 hy.	10.00	HQB-7	2. hy.	19.00	HQD-5	15 mhy.	15.00
HQA-11	.75 hy.	10.00	HQB-8	3.5 hy.	20.00	HQE-1	5 mhy.	6.00
HQA-12	1.25 hy.	11.00	HQB-9	7.5 hy.	21.00	HQE-2	10 mhy.	6.00
HQA-13	2. hy.	11.00	HQB-10	12. hy.	22.00	HQE-3	50 mhy.	7.00
HQA-14	3. hy.	13.00	HQB-11	18. hy.	23.00	HQE-4	100 mhy.	7.50
HQA-15	5. hy.	14.00	HQB-12	25. hy.	24.00	HQE-5	200 mhy.	8.00

## UTC INTERSTAGE AND LINE FILTERS

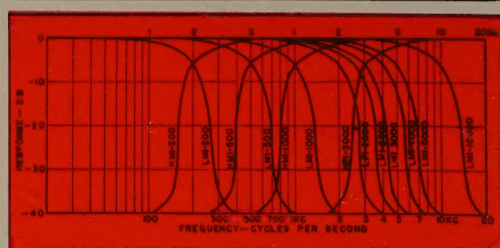


**FILTER CASE M**

1 3/16" x 1 11/16",  
1 5/8" x 2 1/2" High



These U.T.C. stock units take care of most common filter applications. The interstage filters, BMI (band pass), HMI (high pass), and LMI (low pass), have a nominal impedance at 10,000 ohms. The line filters, BML (band pass), HML (high pass), and LML (low pass), are intended for use in 500/600 ohm circuits. All units are shielded for low pickup (150 mv/gauss) and are hermetically sealed.



**STOCK FREQUENCIES**  
(Number after letters is frequency)  
Net Price \$25.00

BMI-60	BMI-1500	LMI-200	BML-400
BMI-100	BMI-3000	LMI-500	BML-1000
BMI-120	BMI-10000	LMI-1000	HML-200
BMI-400	HMI-200	LMI-2000	HML-500
BMI-500	HMI-500	LMI-3000	LML-1000
BMI-750	HMI-1000	LMI-5000	LML-2500
BMI-1000	HMI-3000	LMI-10000	LML-4000
			LML-12000

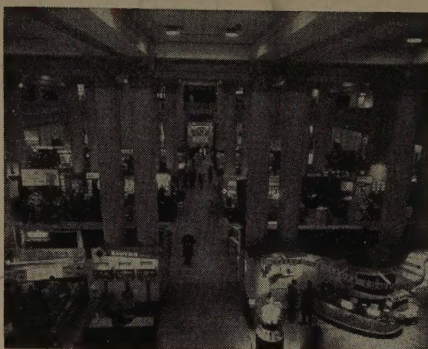
*United Transformer Co.*  
150 VARICK STREET • NEW YORK 13, N. Y.  
EXPORT DIVISION: 13 EAST 40th STREET, NEW YORK 16, N. Y., CABLES: "ARLAB"

# What to SEE at The Radio Engineering Show

March 3-6, 1952 at Grand Central Palace, New York

## 355 Exhibits of Radio-Electronic Equipment

Firm	Booth
<b>Ace Engineering &amp; Machine Co., Inc.</b> Philadelphia 40, Pa.	350, 352
An Ace cell type shielded room, panel construction, showing construction details, power line entrances, filters, method of air conditioning, access doors for conveyor production.	
<b>Advance Electric &amp; Relay Co., Burbank, Calif.</b>	221
Electrical relays.	
<b>Aerovox Corp., New Bedford, Mass.</b>	62
Capacitors, filters, resistors.	
<b>Aircraft-Marine Products, Inc., Harrisburg, Pa.</b>	475
Solderless terminals and connectors and automatic machines for applying them. Amplifilm high performance dielectric, high voltage capacitors, radar pulse networks (Capitron pulse forming networks), "Polyzol" A new dielectric Polymer.	
<b>Air-Marine Motors, Inc., Seaford, L.I., N.Y.</b>	406
Subfractional horsepower motors 60, 400 cps, variable frequency. Centrifugal blowers and axial fan units—60,400 cps, and variable frequency. Control and low inertia motors.	
<b>Airpax Products Co., Baltimore 20, Md.</b>	477
Choppers, vibrators, transformers, vibrator power supplies, vibrator inverters, and servo equipment using our choppers.	
<b>Airtron, Inc., Linden, N.J.</b>	356
Flexible and rigid waveguides, dummy loads, directional couplers, mixer assemblies, duplexer assemblies, waveguide switches.	
<b>Alden Electronic &amp; Impulse Recording Equipment Co., Westboro, Mass.</b>	474
New recorders using electrosensitive recording paper including the Alden Magazine recorder, which records 3 channels on 1/4" record; the Alden Multi Stylus Recorder which records 25 channels in 4 1/2" width; and integral parts for those who want to build their own recorder such as helices, paper holder feed mechanisms etc.	
<b>Alden Products Co., Brockton 64, Mass.</b>	N-3
Indicator lights, fuseholders, ac outlets, dial light sockets, tube cap connectors for all applications. Plugs and Sockets: non-interchangeable, detachable terminal, hi-voltage disconnect, miniature, cathode-ray tube, tuning eye. Components for test equipment: Sockets, adapters, test jacks, analyzer kits. Components for plug-in unit construction. Computer component, plugs and keys, line cords.	
<b>Allegheny Ludlum Steel Corp., Brackenridge, Pa.</b>	25-26
See: Arnold Engineering.	
<b>Allied Control Co., Inc., New York 21, N.Y.</b>	279
Electrical relays, and coils.	
<b>Alpha Metals, Inc., Brooklyn 1, N.Y.</b>	326
Solders, Cen-Tri-Core energized rosin filled solder, wire solder, foil, powder, preforms.	
<b>Alpha Wire Corp., New York 13, N.Y.</b>	471
Insulated and uninsulated copper wire and cable, government specification wire and cable, electronic hook-up wire, multi-conductor intercommunication cable, test lead wire.	
<b>Altec Lansing Corp., New York 13, N.Y.</b>	309, 311
Speech input equipment: consoles, remote mixers, plug-in amplifiers, microphones, transformers, speakers, amplifiers, inter-modulation test equipment, AM-FM tuners, horns, driver units.	
<b>American Lava Corp., Chattanooga 5, Tenn.</b>	64
Ceramic insulators for radio, television, radar, electronic components, wire com-	



Firm	Booth
communications, control equipment, and household appliances.	
<b>American Phenolic Corp., Chicago 50, Ill.</b>	111, 112
Coaxial cables, polyethylene and teflon. 300 ohm twin-lead. rf connectors, AN Connectors and fittings, industrial connectors, AN conduit and fittings, television antennas, radio components and hardware, plastics for electronics.	
<b>American Structural Products Co., Industrial &amp; Electronic Div., Toledo 1, Ohio.</b>	89, 90
Technical glassware for electrical and electronics industry, principally cathode-ray bulbs.	
<b>American Television &amp; Radio Co., St. Paul 1, Minn.</b>	202
Light and heavy duty vibrators, vibrator power supplies, dc-ac inverters, and battery eliminators.	
<b>Ampex Electronic Corp., Brooklyn 1, N.Y.</b>	10-12
Transmitting and power tubes, x-ray tubes and rectifiers, Geiger-Mueller tubes, vacuum capacitors, magnetrons, hydrogen thyatrons and various uhf types and subminiatures.	
<b>Ampex Electric Corp., Redwood City, Calif.</b>	324
Tape recorders for instrumentation.	
<b>Amplifier Corp. of America, New York 13, N.Y.</b>	317
Magnetic tape recorders, particularly a newly developed midget, battery-operated unit. Audio-amplifiers and regulated power supplies.	
<b>Anchor Metal Co., New York 13, N.Y.</b>	217
Shurflo rosin core, and Shurflo special rosin core solders. Bar solders, solid wire preforms.	
<b>Andrew Corp., Chicago 19, Ill.</b>	N-9
VHF and UHF antennas, transmission lines, and assorted equipment.	
<b>Anton Electronic Labs., Inc., Brooklyn 6, N.Y.</b>	390
Corona discharge voltage regulators, Geiger	

40 YEARS  
1912 1952

**SETS THE PACE**

**Come and See  
355 Exhibits**

**Radio Engineering Show - March 3-6,  
Grand Central Palace New York City 1952**

## Seven Million Dollars Worth of Components, Tools and Materials

Firm	Booth
counter tubes and Geiger counter equipment. High intensity radiological monitoring instrument, the AN/PDR-32 which was developed for the Navy by the Anton.	
<b>Approved Electronic Instrument Corp., New York 6, N.Y.</b>	314B
AM/FM tuner, TV pattern generator, FM/TV sweep signal generator, field strength meter, audio amplifiers, pre-amplifiers, power supply, and AM tuner.	
<b>Arco Electronics, Inc., New York 13, N.Y.</b>	338
Molded Mica Capacitors, Steatite Encased Paper Tubular Capacitors, Variable Mica Compression Type Trimmers and Padders, and Silver High K Tubular and Disc Ceramics.	
<b>Arnold Engineering Co., Marengo, Ill. 25, 26</b>	
Permanent Magnets: Cast and sintered Alnico; cast cobalt; Remalloy and Vicalloy high permeability materials, Mopermalloy powder Cores; Deltamax, Perm-alloy, Supermalloy, Mumetal, Silectron and 4750 tape wound cores; "C" cores of Silectron (grain oriented silicon steel), Perm-alloy and Deltamax; Permendur hot rolled bars, forgings and castings.	
<b>Arrow Electronics, Inc., New York 7, N.Y.</b>	318
Jobber: Audio equipment and industrial equipment.	
<b>Atomic Instrument Co., Cambridge 39, Mass.</b>	396A
Glow Transfer Counter, Rapid data Scaler and Printer, Automatic Scaler with built-in linear amplifier, calibrated reference sources, beta emitting. Linear amplifiers, scintillation head, complete model 1030 decade scaler, Libby-Kulp screen wall counter.	
<b>Audio Devices, Inc., New York 22, N.Y.</b>	316
Audiorecording blanks, Audiotape—magnetic recording tape. Audiofilm—magnetic recording film. Audiopoints—recording and playback styli.	
<b>Audio &amp; Video Products Corp., New York 19, N.Y.</b>	485
Special magnetic tape recorders developed by the Ampex Electric Corp. for military and scientific research, data recording, telemetering, vibration studies, and shock analysis. Engineering representatives are in attendance for discussions of the applications of magnetic tape equipment for the storage of information. 100 KC tape recorder and special low wow and low flutter equipment.	
<b>Automatic Electric Sales Corp., Chicago 7, Ill.</b>	290
Telephone type relays—sealed and non-sealed; aircraft and AN types; also regular. Rotary stepping switches of small size and high speed characteristics; extremely rugged and long lived. Manually operated lever key switches. Hermetically sealed rotary stepping switches.	
<b>Avery Adhesive Label Corp., Monrovia, Calif.</b>	467, 468
Kum-Kleen pressure-sensitive labels and labeling methods for: product identification, printed circuits, trademarks, installation instructions, warning and inspection markers. Kum-Kleen electric label dispenser.	
<b>Avion Instrument Corp., Paramus, N.J.</b>	333
Sweep Signal Generator, Magnetic data storage drum, Plug-in amplifier unit.	
<b>Ballantine Laboratories, Inc., Bonton, N.J.</b>	100
Sensitive electronic voltmeters; decade amplifiers, voltage multipliers, precision shunt resistors.	
<b>Barker &amp; Williamson, Inc., Upper Darby, Pa.</b>	N-2
Coils capacitors, components, and test equipment.	

(Continued on page 2A)

Need something special

in

**TEFLON**

or **KEL-F**

Let

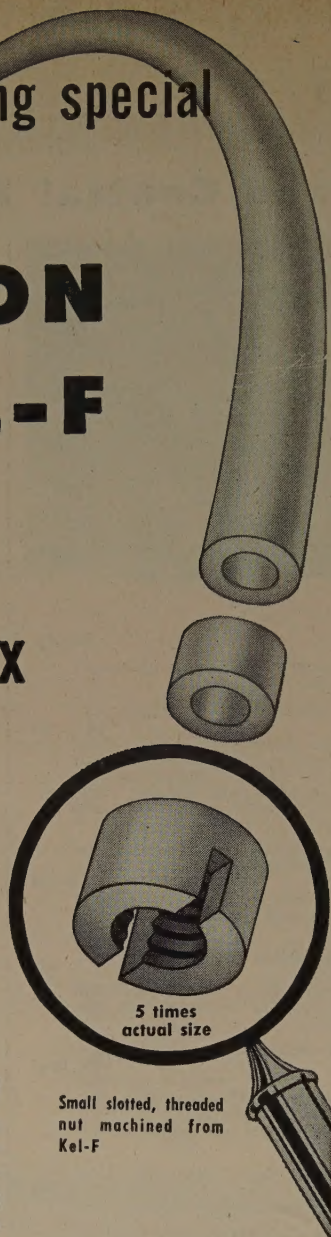
**RESISTOFLEX**

make it

and get

top quality

production



Small slotted, threaded nut machined from Kel-F

At Resistoflex, extrusion and molding equipment for "Teflon"\* and "Kel-F"† was expressly designed to achieve the exact conditions necessary for complete conversion without degradation.

This assures you utmost stability and inertness in these fluorocarbon resins for high frequency insulation over a wide range of temperatures, and under the severest corrosive conditions.

In addition, Resistoflex offers the optimum tensile strength and "plastic memory" in these thermoplastics. They're free from internal strain which means better machinability and longer service life.

Rigid control over processing conditions combines *uniformity* of their outstanding properties with *dimensional* uniformity to give maximum production schedules and lower fabrication costs.

Send in coupon for more data on Teflon and Kel-F produced under our "FLUOROFLEX" trade mark.

\* DuPont trade mark for its tetrafluoroethylene resin.  
† Trade mark of The M. W. Kellogg Co.

*For out of the ordinary  
engineering with synthetics*

**RESISTOFLEX**

RESISTOFLEX CORPORATION, Belleville 9, N. J.

SEND NEW BULLETIN containing technical data and information on Fluoroflex rod, sheet and shapes

NAME..... TITLE.....

COMPANY.....

ADDRESS.....

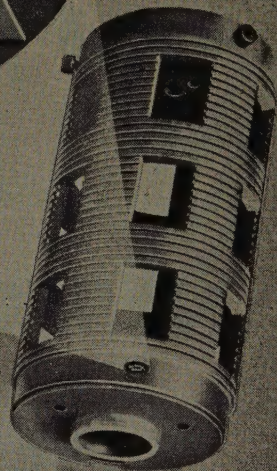
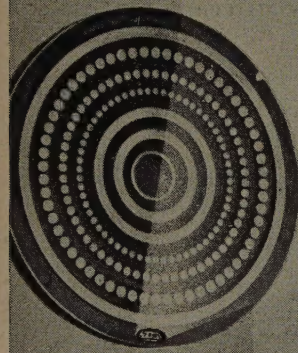
## What to see at the Radio Engineering Show

(Continued from page 1A)

- | Firm  | Booth    |
|---|----------|
| Barry Corp., Watertown 72, Mass.  | 284, 285 |
| All-metl Barrymounts for airborne equipment. Ruggedized aircraft mounting bases for airborne equipment. Ship-board shock isolators for naval equipment. Industrial vibration isolators for commercial equipment.  |          |
| Bart Laboratories Co., Inc., Belleville 9, N.J.   | 347      |
| Rigid waveguide components, waveguide antennae, parabolic and spherical reflecting mirrors, tuning cavities.  |          |
| Beam Instruments Corp., New York 1, N.Y.  | 223      |
| Cossor Oscillographs, oscillograph cameras, and oscillograph motor drives. Best vacuum-junctions: uhf and standard types and special types to order. Sterling wire and cables: radio, multi conductor, coaxial and TV.  |          |
| Bendix Aviation Corp., Red Bank Division, Red Bank, N.J.  | 14-17    |
| Dynamotors to meet MIL-D-24, regulated dynamotors, high temperature motors, dc timers, and inverters. Special and ruggedized vacuum tubes.  |          |
| Bendix Radio Division, Baltimore 4, Md.   | 14-17    |
| Type MRT-6 Command-Air Series mobile communications unit. Type MRT-3 Railmaster communications unit. Type AN/ARC-33 uhf Multi-Channel communications unit. Type MI-51-A Amspeaker. Type GDF-2 vhf direction finding system. MN-35D navigation receiver.   |          |
| Scintilla-Magneto Div., Sidney, N.Y.  | 14-17    |
| Electrical connectors, ignition analyzers miscellaneous, ignition pieces.   |          |
| Eclipse-Pioneer Division, Teterboro, N.J.   | 14-17    |
| Precision components for servo-mechanism and computing equipment including synchros, low inertia motors, gyros, and remote indicating-transmitting systems.   |          |
| Berkeley Scientific Corp., Richmond, Calif.   | 399      |
| Electronic tachometer, direct reading frequency meter, double pulse generator, time interval meter, electronic decimal counting units, preset electronic counters, nuclear scalars, count rate meters.  |          |
| Berlant Associates, Los Angeles 16, Calif.  | 314A     |
| "Network" Magnetic tape recorders, "Professional" Magnetic tape recorders, microphone mixer preamplifiers.  |          |
| Beta Electric Corp., New York 29, N.Y.  | S-21     |
| High voltage power supplies, kilovoltmeters, portable projection oscilloscopes, electronic microammeters.   |          |
| Bird Electronic Corp., Cleveland 14, Ohio   | 243      |
| RF wattmeters, coaxial switches, coaxial load resistors, and rf filters.  |          |
| Bliley Electric Co., Erie, Pa.  | 251      |
| Quartz Crystals, crystal ovens, quartz delay lines, frequency standard, crystal controlled oscillators.   |          |
| Bodnar Industries, Inc., New Rochelle, N.Y.   | 506      |
| AN-P-89 Edge-lighted plastic panels, dials, knobs, etc., for electronic equipment. Electronic telegraph repeaters, terminals, and power supplies.   |          |
| Boesch Mfg. Co., Inc., Danbury, Conn.   | 306      |
| Hand operated type toroidal winding machine. Automatic type toroidal winding machine with full equipment including shuttles. Automatic type toroidal winding machine with 12 inch shuttle. Automatic type toroidal winding machine with continuous winding assembly. Automatic type toroidal winding machine for winding miniature size coils. Automatic type toroidal winding machine with square window attachment. |          |
| Bogue Electric Mfg. Co., Paterson 3, N.J.   | 407      |
| 400 cps motor generator set, magnetic amplifier, selenium rectifiers, and a servo system.   |          |
| Bond Electronics Corp., Springfield, N.J.   | 503      |
| Precision wire-wound resistors, wire wound products, coils and coil assemblies.   |          |
| Boonton Radio Corp., Boonton, N.J.  | 276, 277 |
| Q-Meters, G-Meter, FM-AM signal generator, Univerter, and FM Signal generator.  |          |
| Borg Corp., Borg Equip. Div., Janesville, Wis.  | 272      |
| Precision ten-turn potentiometer, trade-named Micropot. Ten-turn counting dial-Microdial.   |          |

(Continued on page 46A)

# This is the Hallmark of the Ideal Insulation



## FOR ALL FREQUENCIES

Mycalex, the ideal insulation, offers low loss and high dielectric strength. It is impervious to oil or water, free from carbonization, withstands high temperature and humidity. Mycalex remains dimensionally stable permanently and possesses excellent mechanical characteristics. In its present high state of development, Mycalex combines every important insulating advantage—including economy. Mycalex is available in sheets and rods, can be injection or compression molded to close tolerance, is readily machineable, can be tapped, drilled, threaded and ground.

### INJECTION MOLDED GRADES

#### MYCALEX 410

Mycalex 410 is approved fully as Grade L-4B under National Military Establishment Specification JAN-1-10 "Insulating Materials, Ceramics, Radio, Class L."

Power Factor, 1 megacycle	0.0015
Dielectric Constant, 1 megacycle	9.2
Loss Factor, 1 megacycle	0.014
Dielectric Strength, volts/mil	400
Volume Resistivity, ohm/cm	$1 \times 10^{15}$
Max. Safe Operating Temp., °C	350
Water Absorption, % in 24 hours	nil
Tensile Strength, psi	6000

#### MYCALEX 410X

Mycalex 410X can be injection molded, with or without metal inserts, to extremely close tolerances.

Power Factor, 1 megacycle	0.012
Dielectric Constant, 1 megacycle	6.9
Loss factor, 1 megacycle	0.084
Dielectric Strength, volts/mil	400
Volume Resistivity, ohm/cm	$5 \times 10^{14}$
Max. Safe Operating Temp., °C	350
Water Absorption, % in 24 hours	nil
Tensile Strength, psi	6000

### MACHINEABLE GRADES

#### MYCALEX 400

Mycalex 400 is approved fully as Grade L-4A under National Military Establishment Specification JAN-1-10 "Insulating Materials, Ceramics, Radio, Class L."

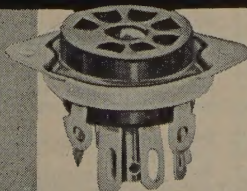
Power Factor, 1 megacycle	0.0018
Dielectric Constant, 1 megacycle	7.4
Loss Factor, 1 megacycle	0.013
Dielectric Strength, volts/mil	500
Volume Resistivity, ohm/cm	$2 \times 10^{15}$
Arc Resistance, seconds	300
Max. Safe Operating Temp., °C	370
Water Absorption, % in 24 hours	nil
Tensile Strength, psi	6000

#### MYCALEX K-10

Mycalex K-10 conforms fully to Grade HIC5H4 under National Military Establishment Specification JAN-1-12.

Dielectric Constant, 1 megacycle	10.6
Q Factor, 1 megacycle	300
Loss Factor, 1 megacycle	0.034
Dielectric Strength, volts/mil (0.10 in. thickness)	270
Fractional Decrease of Capacitance with Temperature Change	0.0056
Fractional Increase of Capacitance with Temperature Change	0.0076

### LOW-LOSS MINIATURE TUBE SOCKETS



**ECONOMICAL**—Comparative in cost to ordinary phenolic sockets, but far superior electrically. Dimensional accuracy unexcelled.

**AVAILABLE IN TWO GRADES**—Mycalex 410 fully approved as Grade L-4B under N.M.E.S. JAN-1-10 "Insulating Materials, Ceramics, Radio, Class L." Mycalex 410X offers lower cost with insulating properties exceeding those of general purpose phenolics. Both Mycalex 410 and 410X Tube Sockets are supplied in 7 pin, 9 pin and subminiature. All are precision molded for highest accuracy.

#### MYCALEX K

embraces an entire series of capacitor dielectrics, each with specific characteristics. These can be supplied on special order in sheets 14"x18" in area and from 1/8" to 1" in thickness, also available in rods. MYCALEX K can be machined to close tolerance or molded.

WRITE TODAY ON YOUR LETTERHEAD FOR ILLUSTRATED LITERATURE, OR SEND BLUEPRINTS FOR ESTIMATES—NO OBLIGATION

## MYCALEX CORPORATION OF AMERICA

Owners of 'MYCALEX' Patents and Trade-Marks

Executive Offices: 30 ROCKEFELLER PLAZA, NEW YORK 20 — Plant & General Offices: CLIFTON, N.J.

See our exhibit at the IRE Show, Grand Central Palace, New York—Booths #82, 83

# Take the "bugs"

## out of

## R-F measurements

## and meet

## military specifications

# ACE *Pre-built* SCREEN ROOMS

100 db. attenuation from 0.15 to  
10,000 mc. (or higher on special order)



- ### Typical uses
1. Evaluation and suppression of radio interference.
  2. Susceptibility and spurious radiation tests.
  3. Radio inspection and quality control.
  4. Type testing of electrical and electronic equipment.
  5. Area background radio interference elimination.
- A list of government laboratories and industrial plants using Ace Screen Rooms is available on request.

Write, Wire or 'Phone for Details

**ACE ENGINEERING and MACHINE CO., INC.**

3644 N. Lawrence St.

Philadelphia 40, Pa.

Telephone:  
REgent 9-1019

Meet Us at the I.R.E. Show, Booths 350-352

## What to see at the Radio Engineering Show

(Continued from page 2A)

Firm	Booth
W. H. Brady Co., Chippewa Falls, Wis.	258
Self-sticking wire markers, special labels, safety signs, masks, and gaskets.	
Brentano's Technical Dept., New York 19, N.Y.	259
Latest technical books of all publishers in the related fields of radio, television, electronics, nuclear physics, and related mathematical subjects.	
British Industries Corp., New York 13, N.Y.	270
Garrard record changers and phono equipment, Ersin Multicore solder, KT66 power amplifying tube, leak "Point-One" amplifiers, Douglas and MacAdie automatic coil winding machines, Wharfedale speakers, Avometers (test equipment).	
Browning Laboratories, Inc., Winchester, Mass.	S-12, S-13
FM Tuner; FM-AM Tuners; FM Modulation monitor; oscillosynchroscope; synchroscope.	
Brujac Electronic Corp., New York, N.Y.	S-18, S-19
Electronic measuring instruments and components.	
Brush Development Co., Cleveland 14, Ohio	70, 71, 72
Cabinet rack with one type BL-246 Six Channel Combination Oscillograph, two type BL-962 dc Amplifiers and one type BL-360 Universal Strain Amplifier. One BL-928 Dual Channel Amplifier with type BL-201AR Single Channel Oscillograph with slow speed paper drive and Event Marker and BL-933 Takeup Reel. One BL-312 Universal Strain Bridge Switch and BL-222 Dual Channel Electric and Ink Writing Oscillograph. Piezoelectric crystal and ceramic elements. Laboratory generator and transducer.	
Burlington Instrument Co., Burlington, Iowa	228
Electrical indicating instruments, ac and dc, both standard and hermetically sealed.	
Burroughs Adding Mach. Co., Philadelphia 23, Pa.	413
Pulse control units—a line of standardized electronic building blocks: Pulse generators, flip flops, coincidence detectors, mixers, pulse gates, etc., that can be combined in standard relay racks, operated from standard voltages, to form complex circuits.	
Bussmann Mfg. Co., St. Louis 7, Mo.	371
Fuses, fuse clips, fuse blocks and fuse holders.	
CBS-Remington-Rand, Vericolor Hall	380
See: Columbia Broadcasting	
C. G. S. Laboratories, Inc., Stamford 1, Conn.	N-4
S-Band Oscillator Cavity. Peak pulse voltmeter "Incredutor," line of variable controlled inductors.	
C&H Supply Company, Seattle 8, Wash.	346
Metal-Cal identification name plates, and circuit diagrams.	
Caldwell-Clements, Inc., New York 17, N.Y.	253
TELE-TECH—Technical magazine of the radio-television-electronic industries. RADIO & TELEVISION RETAILING—Magazine of radio-TV distribution and maintenance.	
The Calidyne Co., Winchester, Mass	273
Vibration Test Equipment—electro-dynamic Shakers—25, 450, and 2,500 pound force output. Electro-dynamic vibration pickup and Accelerometer calibration systems, accelerometers and accelerometer couplers, Vibrascopes, Calivolters, vibration meter, and signal monitor for velocity signal generators.	
Cambridge Thermionic Corp., Cambridge 38, Mass.	287
Soldering terminals, terminal boards, IF and rf coils, electronic hardware (handles, shaft locks, tube clamps, standoffs, etc.) insulated standoffs and feed-thrus (ceramic and phenolic) slug-tuned coil forms (ceramic and phenolic).	

(Continued on page 68A)

*NOW, Mr. Manufacturer...*  
**ALL Du Mont Teletrons are**  
**Guaranteed for 6 months**  
**from date**  
**of installation**



(Complete Information on Request.)

Now Du Mont assures you of six months' protection from the day your receiver is installed in the customer's home, and insures still greater customer-confidence for your brand name. Du Mont offers the best guarantee protection today.

**DU MONT**  
*Teletrons\**

CATHODE-RAY TUBE DIVISION

ALLEN B. DU MONT LABORATORIES, INC., CLIFTON, N. J.

\*Trade-mark

SEE US AT THE RADIO ENGINEERING SHOW, BOOTHS 120 TO 128



# Are you missing any of these IRON CORE ENGINEERING POSSIBILITIES?



## ✓ Smaller tuning units ✓ Less critical materials

By providing electrostatic and electromagnetic protection over that supplied by the can, *Stackpole sleeve cores* permit use of a smaller can and enable it to be made from less critical and costly materials.



## ✓ Higher Q ✓ Smaller assemblies ✓ Simplified tuning

*Stackpole threaded type iron cores* eliminate the usual brass core screw from the field of the coil, thus greatly increasing efficiency.

## ✓ Better, more accurate permeability tuning

Extra density of molding pressure extends evenly over the entire length of *Stackpole side-molded cores* to assure highly uniform permeability.

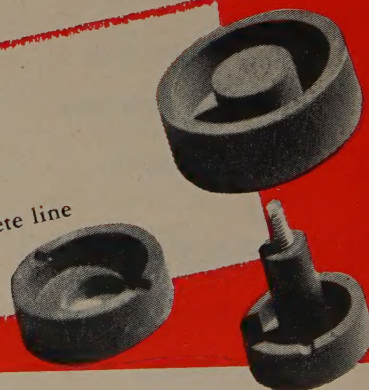
End  
Molded

Side  
Molded



## ✓ No shielding problems ✓ High Q in small space

Pioneers in *cup cores*, *Stackpole* offers a complete line of standard and special self-shielding types.



There's no substitute for molded iron cores in a long list of applications—electrically, mechanically or economically!

Besides all regular styles for high, low and standard frequencies, *Stackpole* offers

full facilities for the quality-controlled production of almost any needed special type. Write for Catalog RC-8 to Electronic Components Division, *Stackpole Carbon Company*, St. Marys, Pa.

# STACKPOLE

Where the  
Requirements  
are Extreme...

## Use SILVER GRAPHALLOY

For extraordinary  
electrical performance



THE SUPREME BRUSH  
AND CONTACT MATERIAL

### for BRUSHES

- for high current density
- minimum wear
- low contact drop
- low electrical noise
- self-lubrication

### for CONTACTS

- for low resistance
- non-welding character

\* Graphalloy is a special  
silver-impregnated graphite

Accumulated design experience counts —  
call on us!

## GRAPHITE METALLIZING CORPORATION

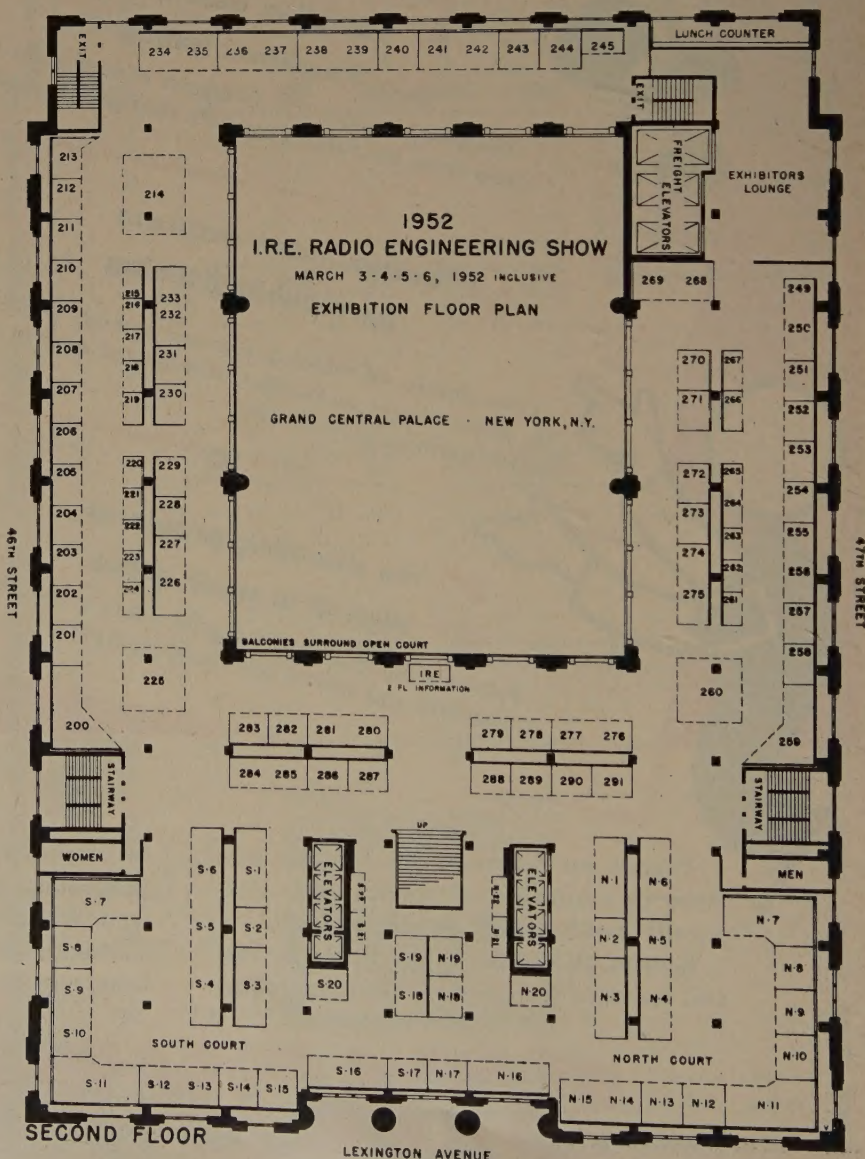
1001 NEPPERHAN AVENUE, YONKERS 3, NEW YORK

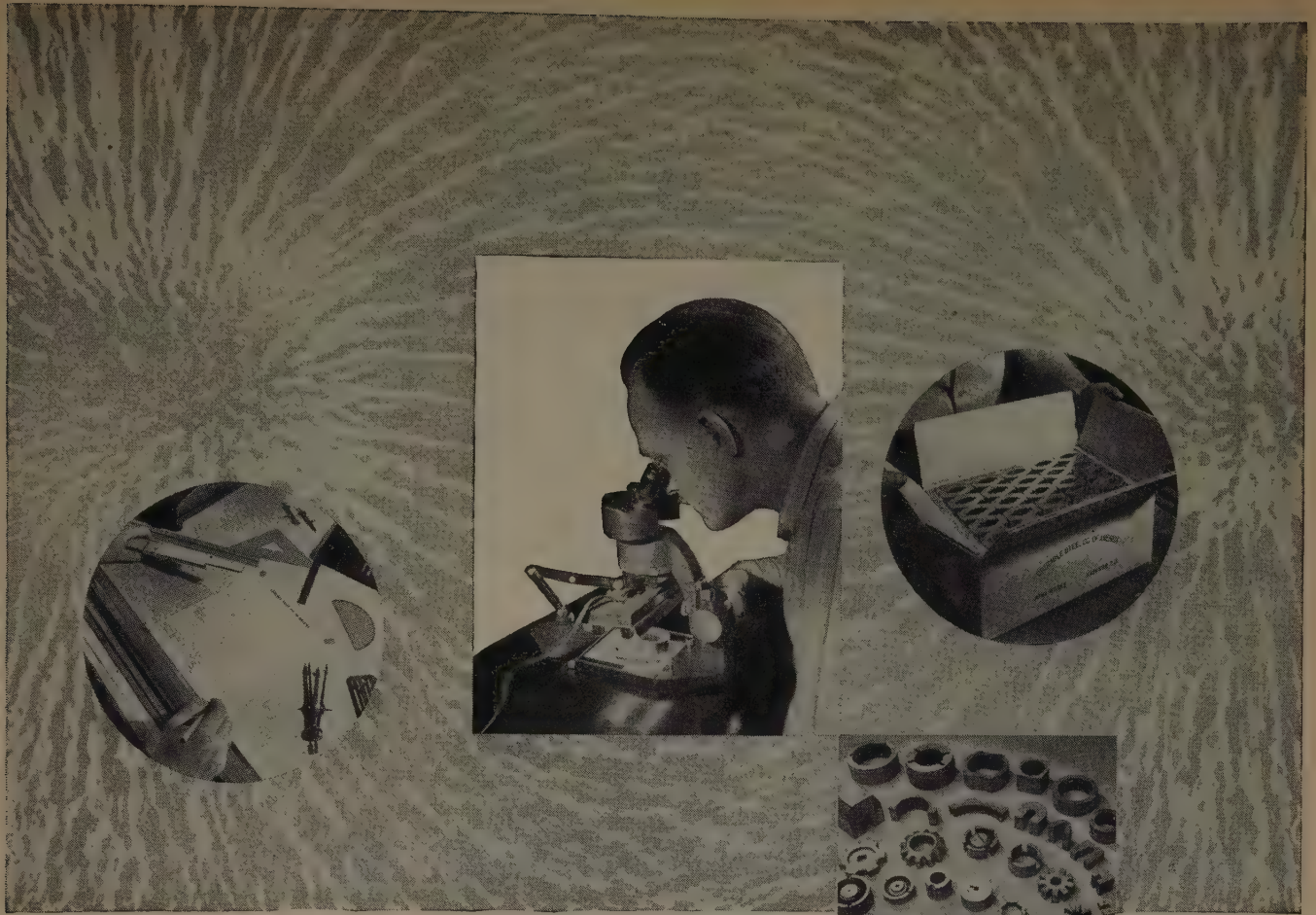
## What to see at the Radio Engineering Show

(Continued from page 68A)

Firm	Booth	Firm	Booth
Sigmund Cohn Corp., New York 38, N.Y.	283	Condenser Products Co., Chicago 26, Ill.	N-17
Precious metal products, very small wires, gold plated wires, and enameled wires; gold and rhodium plating solutions.		Plasticon, and glasslike capacitors. Hi-Volt power supplies, Pulse forming networks.	
Coil Winding Equipment Co., Oyster Bay, L.I., N.Y.	353, 355	Consolidated Engineering Corp., Pasadena 8, Calif.	395B
Coil winding machinery and related products for the winding of a wide variety of coil types. Machines for production and laboratory use will be in actual operation.		Recording oscillographs, pickups, and recording measurement instruments. Leak detector for leak testing any pressure or vacuum systems.	
Collins Radio Co., Cedar Rapids, Iowa	75-80	Consolidated Vultee Aircraft Corp., San Diego 12, Calif.	500
Aircraft communications and navigation equipment, amateur radio transmitters and receivers, equipment for AM and FM broadcasting, and electronics equipment for the department of defense. Aircraft instrument landing approach simulator.		High speed cathode-ray message display. "Charactron."	
Columbia Broadcasting System, Vericolor Hall, New York 22, N.Y.	380	Continental Carbon, Inc., Cleveland 11, Ohio	224
Industrial color television equipment and systems. AM-FM-TV Broadcasting, Radio and TV sets, wire recorders, phonograph records, transcriptions, phonographs, wood cabinets and products.		"Nobleloy" metal film precision resistors, low power wire wound resistors, composition resistors. Suppressors: automotive ignition, and oil burner types.	
Columbia Technical Corp., New York 22, N.Y.	436	Continental Electric Co., Geneva, Ill.	375
High-frequency coaxial cables manufactured by Hackethal Wire and Cable Company, Hannover, West Germany.		Complete line of phototubes, rectifiers, and thyatrons.	
		Copperweld Steel Co., Glassport, Pa.	434
		Samples of Copperweld wire products. An animated display showing how Copperweld is made by the Molten-Welding process.	

(Continued on page 82A)





## quality magnets from start to finish



VISIT OUR BOOTH #504  
I.R.E. SHOW  
GRAND CENTRAL PALACE  
N. Y. C. MARCH 3-6, 1952

From the first engineering drawing to the final inspection and shipping, Crucible Permanent Alnico Magnets receive the same careful attention and workmanship that is found in all Crucible specialty steels. Rigid quality control at every step in the production of Crucible Alnico . . . with a keen devotion to detail . . . is the reason that users of Crucible Permanent Alnico Magnets have found that from Crucible they get a better magnet with *higher gap flux per unit weight*.

Crucible Alnico Magnets are serving successfully in thousands of varied applications. The experience of Crucible's alert staff of metallurgists and engineers is freely available to you. Take advantage of Crucible's half century of specialty steel leadership. When you think of permanent magnets . . . call Crucible. CRUCIBLE STEEL COMPANY OF AMERICA, General Sales Offices, Oliver Building, Pittsburgh, Pa.

**CRUCIBLE**

first name in special purpose steels

52 years of *Fine* steelmaking

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PROCEEDINGS OF THE I.R.E.

February, 1952

81A

when you need a

# QUALITY OSCILLATOR



## Model M-2 Oscillator Is Your Answer

The unique SIE oscillator circuit which has no lower limit to its possible frequency of oscillation is responsible for the excellent low frequency performance of the Model M-2 and other SIE oscillators.

### SPECIFICATIONS

Range: 1 cps to 120,000 cps  
Calibration: within 1½% plus 1/10 cycle  
Output circuits: 20 volts or 20 millamps and 1 volt at 300 ohms constant impedance  
Amplitude stability: Plus or minus ½ db  
**UNDESIRE VOLTAGES**  
Power Supply Noise: Less than 1/100% of output signal  
Power Line Surge: Less than 1/10% of output signal  
Harmonic Distortion: Less than 2/10% from 20 cps to 15,000 cps, Less than 1% at all other frequencies  
Microphonic Noise: Less than 1/100% of output signal

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ELECTRONICS CO.**

1831 POST OAK ROAD  
HOUSTON 19, TEXAS

434 SEVENTH AVE. EAST — CALGARY, ALBERTA, CANADA

## What to see at the Radio Engineering Show

(Continued from page 70A)

Firm	Booth
Cornell-Dubilier Electric Corp., S. Plainfield, N.J. Capacitors, Vibrators, Antennas, Converters (Vibrator powered).	73, 74
Corning Glass Works, Corning, N.Y. All-glass television bulbs (including new non-glare cylindrical face plate). Special glasses widely used for glass-to-metal seals. Metallized glassware for glass-to-metal seals. Bulbs and tubing for electronic and cathode-ray applications.	30-32
Cossor (Canada) Ltd., Halifax, Nova Scotia, Canada Sec: Beam Instruments.	223
R. W. Cramer Co., Inc., Centerbrook, Conn. Synchronous motors (small 1 rps-¼ rpd output speeds). Dual motors, chart drive motors, interval timers, reset timers, time delay relays, cycle timers, reversing timers, pulse timers, duplex timers, percentage timers, multi-contact timers, running time meters, special timers. Hermetically sealed instruments: circuit reclosing relay, miniature time delay relays, running time meters.	416, 417
Crucible Steel Co. of America, New York 17, N.Y. Permanent magnets in a variety of sizes and shapes, tool, stainless and special purpose steels, including stainless tubing.	504
Curtis Dev. & Mfg. Co. Sec: Wally Swank	221
H. L. Dalis, Inc., New York, N.Y. Audio and industrial equipment.	320B
The Daven Co., Newark 4, N.J. Attenuators, audio and rf; output power supply, switches, audio and rf; attenuation network, laboratory and test sets, rf attenuation boxes, communication equipment, Jan-R-93-precision wire wound resistors, signal generator, transmission measuring sets.	94B, 95
Bryan Davis Publishing Co., Inc., New York 17, N.Y. Television Engineering magazine, Service magazine.	288
Tobe Deutschmann Corp., Norwood, Mass. Capacitors, metallized paper, oil and wax impregnated paper, molded paper, high temperature. Filters: Radio TV-Noise suppression, low pass, high pass, band pass, audio. Special products, pulse forming networks, delay lines.	343
Dial Light Co. of America, Inc., New York 3, N.Y. Warning signal indicator, and pilot light assemblies.	46
Diamond Mfg. Co., Wakefield, Mass. Rf coaxial cable connectors and microwave components.	489
Distillation Products Industries, Rochester 3, N.Y. Philips Vacuum gauge, magnetron tube pumping dolly, LD-01 Halogen Sensitive Leak detector, various types of thermocouple vacuum gauges, new designs in crystal coating equipment, the MB-10 booster pump and valve assembly.	241, 242
Wilbur B. Driver Company, Newark 4, N.J. Special alloys for electronic applications.	340, 342
Dumont Electric Corp., New York 34, N.Y. Tubular paper, dry electrolytic, metal clad, bathtub and upright capacitors. "Zero-Loss durenne capacitors." "Thermofilm" dielectric capacitors.	403
Allen B. DuMont Laboratories, Inc., TV Transmitter Division, Clifton, N.J. Sync generator; monochrome scanner; universal color scanner; model studio control room; studio camera with mobile-mount dolly; master control equipment; video switching and mixing equipment.	120-123
Allen B. DuMont Laboratories, Inc., Cathode-Ray Tube Div., Clifton, N.J. Television picture tubes including Selfocus types, cylindrical faceplate tubes, low voltage electrostatic focus tubes, and the 30BP4 Teletron.	124, 125

(Continued on page 86A)



## The Brochure You've Been Waiting For Is

Are you one of the thousands of electronic engineers who has already requested a copy of this important, new, 32 page brochure on hermetic sealing? If not, send your name in today for your FREE copy.

Nothing before has ever been done in this highly specialized field that can compare with this new presentation on glass-metal headers.

Beautifully printed in 3-colors, this brochure will bring you up to date on hermetic sealing, because it shows a remarkable exposition of what HERMETIC SEAL PRODUCTS CO. has achieved in miniature and sub-miniature plugs and seals, as well as in standard-size headers.

# Off The Press!

Years of creative, fruitful effort by HERMETIC have made it the largest exclusive manufacturer of hermetic seals in the world. This company has pioneered and introduced almost every important innovation in this most exacting field.

HERMETIC's specialist-engineers, with such a background, are eager to help you with your problems in the ever-expanding usage of hermetic sealing.

VISIT HERMETIC'S BOOTH NUMBER 129 AT THE 1952 I. R. E. SHOW.



## HERMETIC SEAL PRODUCTS CO.

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# Guthman Coils

for those who put **QUALITY** first!

the edwin i. guthman company  
is the world's largest  
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BURTON BROWNE ADVERTISING

## What to see at the Radio Engineering Show

(Continued from page 82A)

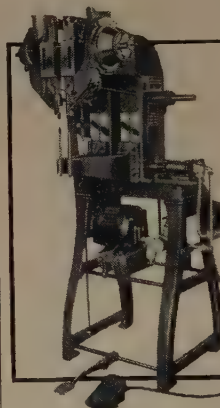
- | Firm   | Booth    |
|--|----------|
| <b>Allen B. DuMont Laboratories, Inc.,</b><br>Instr. Div., Clifton, N.J.   | 126-128  |
| Cathode-ray oscillographs: Type 322 dual-beam; Type 303; Type 294-A; Type 304-HR; Type 334-A; CRO accessories. Oscillograph record cameras: Type 321; Type 295; Type 296; Type 297. Industrial Cathode-ray Tubes: Types K1065; K1056, K1101, K1052, K1098, K1080, K1105, K1084, 3RF-A, 5YP-, 5SP-.   |          |
| <b>DX Radio Products Co., Inc.,</b> Chicago 47, Ill.   | 345A     |
| IF, rf, and discriminator transformers, rf choke coils, toroid off-center coils, toroid reactors, toroid deflection yokes, toroid filters, hermetic sealed focus coils, focus coils, special deflection yokes, special coil assembly, crystals, speakers, horizontal output transformer, ion traps, deflection yokes, TV tuner (Rotorette), quartz crystals. |          |
| <b>Dyna-Labs., Inc.,</b> New York 13, N.Y.   | 409      |
| D-79 Gaussmeter, to measure flux in small gaps, miniature magnetic earphones.  |          |
| <b>Hugh H. Eby, Inc.,</b> Philadelphia 44, Pa.   | 410      |
| Various types of radio—electronic hardware, sockets, plugs, terminal strips and boards. Binding posts fuse holders, etc. Connectors: rack, panel, and pressurized.   |          |
| <b>Eitel-McCullough, Inc.,</b> San Bruno, Calif.   | 36       |
| Diodes, triodes, tetrodes, pentodes, klystrons, cathode-ray, vacuum switches, vacuum capacitors, vacuum pumps, vacuum apparatus, tube hardware, vacuum tube materials and components.  |          |
| <b>Elastic Stop Nut Corp. of America,</b> Union, N.J.  | 458      |
| Self-locking rollpins, and elastic stop nuts.  |          |
| <b>ELCO Corp.,</b> Philadelphia 40, Pa.  | 337      |
| Tube sockets, tube shields and plugs, and connectors. "Varicon" connectors, and plugs and receptacles. New connector systems, miniature in size but high current carrying capacity, flexible and polarity.   |          |
| <b>Electrical Industries, Inc.,</b> Newark 4, N.J.   | 212      |
| Hermetically sealed terminals and headers for use on relays, transformers, and other equipment requiring vacuum tight seals.   |          |
| <b>Electric Reactance Corp.,</b> Olean, N.Y.   | 63       |
| Ceramic capacitors, trimmers, wire wound resistors, printed circuits.  |          |
| <b>Electro Precision Products, Inc.,</b> College Point, L.I., N.Y.   | 431      |
| Coax Connectors, and Microwave Equipment.  |          |
| <b>Electro Motive Mfg. Co., Inc.,</b> Willimantic, Conn.   | 338      |
| See: Arco Electronics, Inc.  |          |
| <b>Electro-Tech Equipment Co.,</b> New York 13, N.Y.   | 411, 412 |
| Electrical measuring instruments, and industrial control equipment, and constant and variable voltage transformers. Selenium rectifiers for industrial needs, Eagle signal timers, and photoswitch.  |          |
| <b>Electronic Associates, Inc.,</b> Long Branch, N.J.  | 98, 99   |
| Model 205 series Variplotter plotting board; automatic curve following equipment for use with analog computers, etc.; automatic digital curve plotting equipment; "EASE" (Electronic Associates Simulation Equipment)—a high-precision, general-purpose analog computer.   |          |
| <b>Electronic Computer Corp.,</b> Brooklyn 17, N.Y.  | 505      |
| Small electronic digital computer. Components for computers.   |          |
| <b>Electronic Devices, Inc.,</b> Brooklyn 15, N.Y.   | 408      |
| Rectifiers: Minisel-subminiature encased selenium rectifiers. Plastisel-miniature electronic selenium rectifiers. Powersel-commercial and power rectifiers. Minisel instrument rectifiers. Rectifier test equipment . . . power supplies. Resistors: carbon resistors.   |          |
| <b>Electronic Instrument Co., Inc.,</b> Brooklyn 11, N.Y.  | 362      |
| Test equipment instruments and kits, including oscilloscopes, vacuum tube voltmeter, signal tracers, signal generators, multimeters, sweep generators, tube testers, comparator bridge, battery eliminators, high voltage probes, high frequency probes, crystals, etc.  |          |

(Continued on page 82A)

IN BOOTH

**N-7**

**RADIO  
ENGINEERING  
SHOW**



**SEE**

the Demonstration of  
the double rivet setter  
with pneumatic control  
that instantly gives  
operator choice of two  
sets of Riveting Centers.

Riveting center:  
5/8" to 6".

Rivet capacity:  
1/64" steel Tubular.  
Maximum Length: 5/8".

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FASTENING  
PROBLEM**

*Chicago Rivet  
& MACHINE CO.*

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BELLWOOD, ILLINOIS

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made to YOUR  
Specifications with Close  
or Liberal Tolerances

To large and small manufacturers alike, the Karp Blueprint Man is the symbol of traditional excellence in sheet metal fabrication . . . hallmark of highest quality and value in every class of work, from the most routine to the most exacting.

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Any Metal

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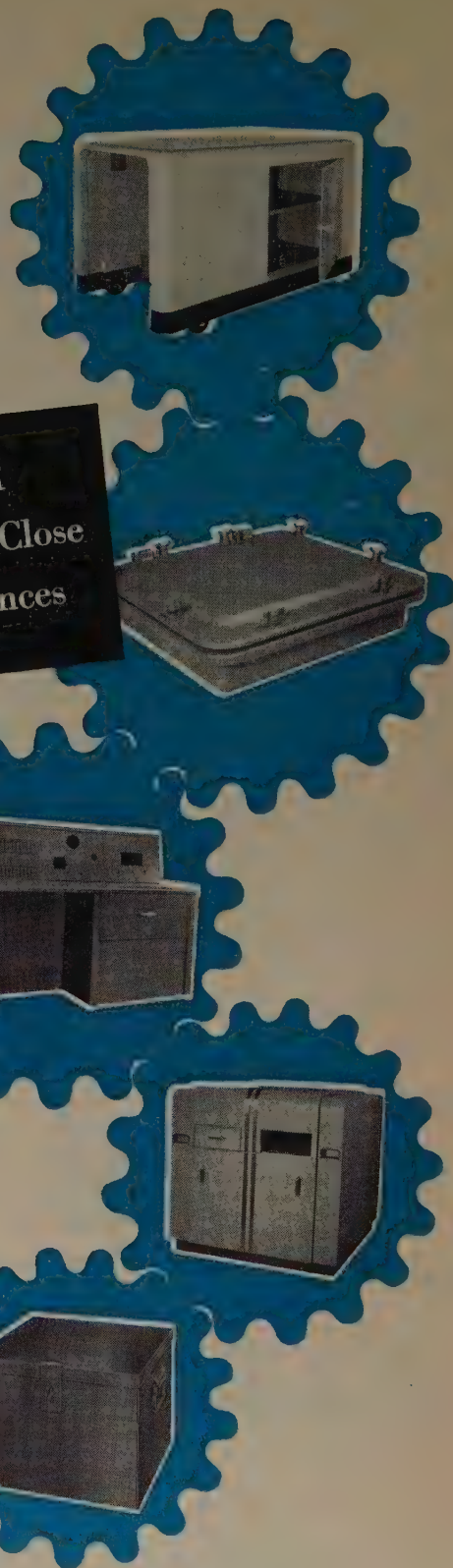
Any Size

Any Quantity

Any Finish

## KARP METAL PRODUCTS CO., INC.

223 63rd STREET • BROOKLYN 20, NEW YORK

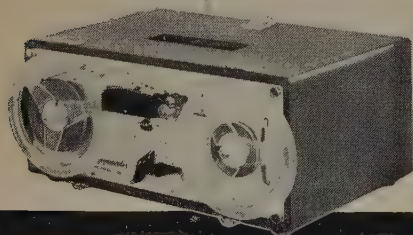


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## SAVE YOUR RESEARCH TIME AND DOLLARS

With a Magnecord tape recorder you can make your industrial research more efficient! A precision recording instrument, the Magnecoder becomes an "audio notebook" to record sound data of actual product test and development. Built for experts, this equipment saves expensive engineering hours in the laboratory or in the field. Used by more engineers than all other professional recorders combined, Magnecoders record with greater fidelity and precision.



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HIGH FIDELITY TAPE RECORDERS FOR INDUSTRY

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360 N. Michigan Avenue, Chicago 1, Illinois

Send me further information on Magnecord  
tape recording for industrial "Sound" Research

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Company.....

Address.....

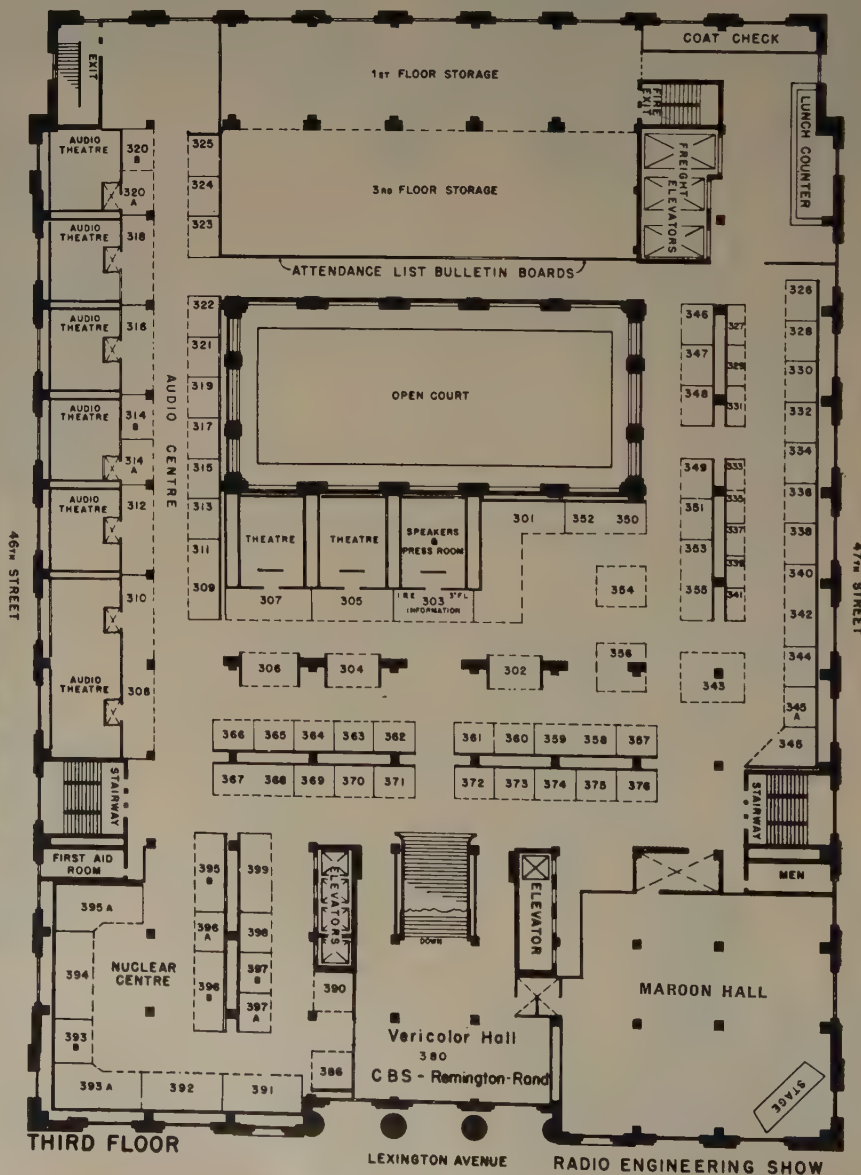
City.....Zone.....State.....

## What to see at the Radio Engineering Show

(Continued from page 86A)

Firm	Booth	Firm	Booth
Electronic Mechanics, Inc., Clifton, N.J. 336 Mykroy (glass bonded mica) Kel-F (Trifluorochloroethylene) Teflon (Tetra- fluoroethylene).		manual sample changer, remote handling tongs. Noise and field intensity meter 20 to 400 mc, impulse generator.	
Electronic Tube Corp., Philadelphia 18, Pa. 274, 275 Multi-channel oscilloscopes, standard, multi-gun and special cathode-ray tubes, dc amplifiers.		Emeloid Co., Inc., Hillside 5, N.J. 472 Printed circuits and fabricated and printed plastic articles such as name- plates and special parts. The printed cir- cuits have finishing operations such as piercing, blanking, assembling, also patent pending flush type for switches.	
Electronics, New York 18, N.Y. 200 See: McGraw-Hill Pub. Co.		Empire Devices, Inc., Bayside, L.I., N.Y. 349 Broadband crystal mixers, noise and dis- tortion analyzer 6 to 110 kc; coaxial at- tenuator pads. Resistive step attenuators, uhf.	
H. R. Ellis, New York 17, N.Y. 244 Airmec Lab., test equipment. Enthoven, H. V., cored solder. Painton & Co. Ltd., Potentiometers-resistors Induction Motors Corp., miniature ac motors. Parmeko, transformers, cans, parts. Belling & Lee, sockets, connectors, filters, fuses. General Accessories Co., sockets, connectors, pilot lights, phone tips. Plastic Process Co., Electro Acoustic.		Engineering Research Associates, Inc., St. Paul 4, Minn. 361 Unit-Magnetic recorder using new boundary-displacement technique; shaft- monitor shaft position indicator. Magnetic recording heads; pulse transformers; pic- tures and descriptive brochures on ERA digital computers and magnetic drum stor- age systems.	
El-Tronics, Inc., Philadelphia 33, Pa. 386 Binary and decade sealing units; portable Geiger-Mueller survey units; portable ionization chambers—cutie pie type; count rate meters and count rate meter attach- ments; Nuclear accessories for labora- tories and hospitals; laboratory audio os- cillator; square wave generator; insulation tester; wide band oscilloscope. Shielded		Erie Resistor Corp., Erie, Pa. 91 Miniaturized ceramic and button silver mica capacitors, printed circuits, stand- off and feed-thru capacitors. High tem- perature (250° C) button silver mica capacitors. Barium titanite piezo electric elements.	

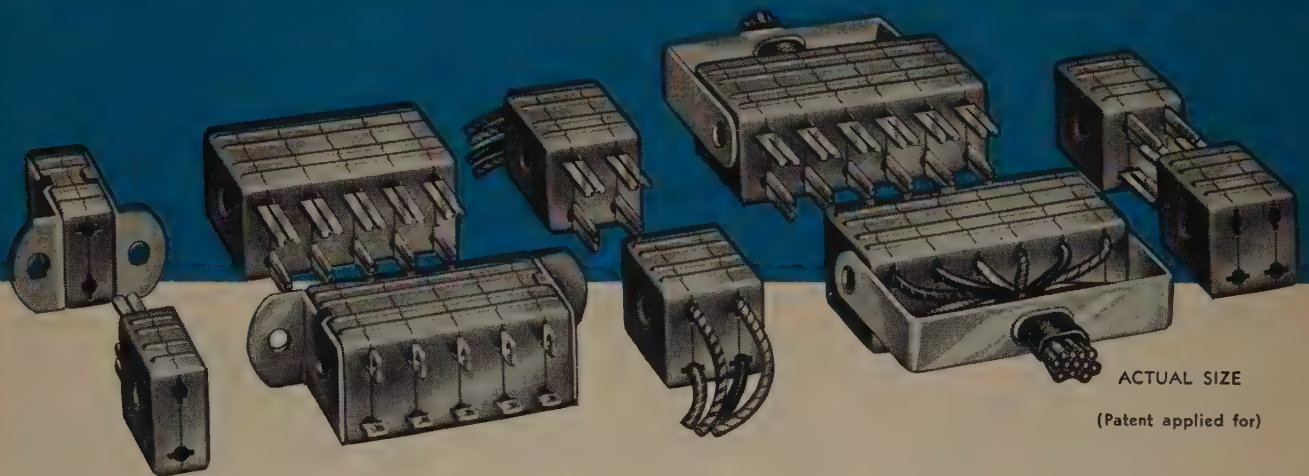
(Continued on page 92A)



THE CONNECTORS THAT "Couldn't Be Invented"... **ELCO'S**

# VARICONS

THE MINIATURE CONNECTORS THAT WORK LIKE GIANTS!



WITH "KEYING CONTROL" VERSATILITY NEVER BEFORE ACHIEVED!

**HOW NEW IS NEW?** You'll never know until you've seen Elco's Varicons! Because Varicons provide the simplest, quickest, most positive means for connecting electronic or electrical circuits ever conceived! Because Varicons introduce "Keying Control," which makes it impossible to connect unmatched parts! And because Varicons, for the first time, makes it possible for you or us to assemble any connector from stock parts!

**HOW NEW IS NEW?** You'll never realize until you see how Varicons' four basic parts give you the maximum number of "Keying Control" variations; plus contact combinations in any number demanded by your specific needs. For the new product you're designing, or the redesign of a present product, you'll want the full, specific Varicon story. We'll have it on your desk by return mail, upon the receipt of your inquiry.

*General Specifications — Male and female elements identical :: Contacts always under pressure; cannot be overstressed or overstrained :: Current rating 30 amps, 115 volts :: Withstanding voltage maximum 4000 volts between closest terminals :: Low contact resistance :: Low capacitance, 300 ohm line spacing :: Easy insertion pressure :: Excellent retention pressure between contacts.*

► The Complete Varicon Story . . . Yours by Return Mail!

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Or Visit Our Booth, No. 337, Radio Engineering Show,  
Grand Central Palace, N. Y. C. March 3-4-5-6

**IF IT'S NEW . . . IF IT'S NEWS . . . IT'S FROM**

**ELCO CORPORATION**  
RADIO • TELEVISION • ELECTRONIC COMPONENTS  
190 W. GLENWOOD AVE., PHILA. 40, PA.

# Subminiature



## Corona Regulators

These miniature and sub-miniature corona voltage regulator tubes have been developed for high voltage, low current applications. Specifically designed for such uses as: counter tube power supplies, photomultiplier tubes, stabilizing the second anode potential of cathode ray tubes, reference voltages for regulator systems, nuclear and cosmic ray research. These tubes have been used in such applications as radio frequency and vibrator high-voltage power supplies. They have excellent regulation, exceedingly long life, and their small size gives them a high degree of space efficiency.

In sufficient quantities these corona regulator tubes can be supplied for any voltage between 450 and 16,000 volts.

### CHARACTERISTICS

	5841	5950	6119
DC STARTING VOLTAGE (VOLTS MAX)	930	730	2050
DC REGULATED VOLTAGE (VOLTS)	900±15	700±15	2,000±30
REGULATED CURRENT RANGE (μa)	2-50	2-50	2-50
VOLTAGE REGULATION (2-50 μa) (%)	1.5	1.5	1.5
BULB SIZE	T-3	T-3	T-3
LIFE	Unlimited by use		

### RATINGS

MAXIMUM REGULATOR TUBE CURRENT (μa)	200
MAXIMUM RELATIVE HUMIDITY (%)	100
AMBIENT TEMPERATURE RANGE (°C)	-65 to +100



BETTER COMPONENTS  
MAKE  
BETTER INSTRUMENTS

**Victoreen Instrument**

Components Division

3800 Perkins Ave.

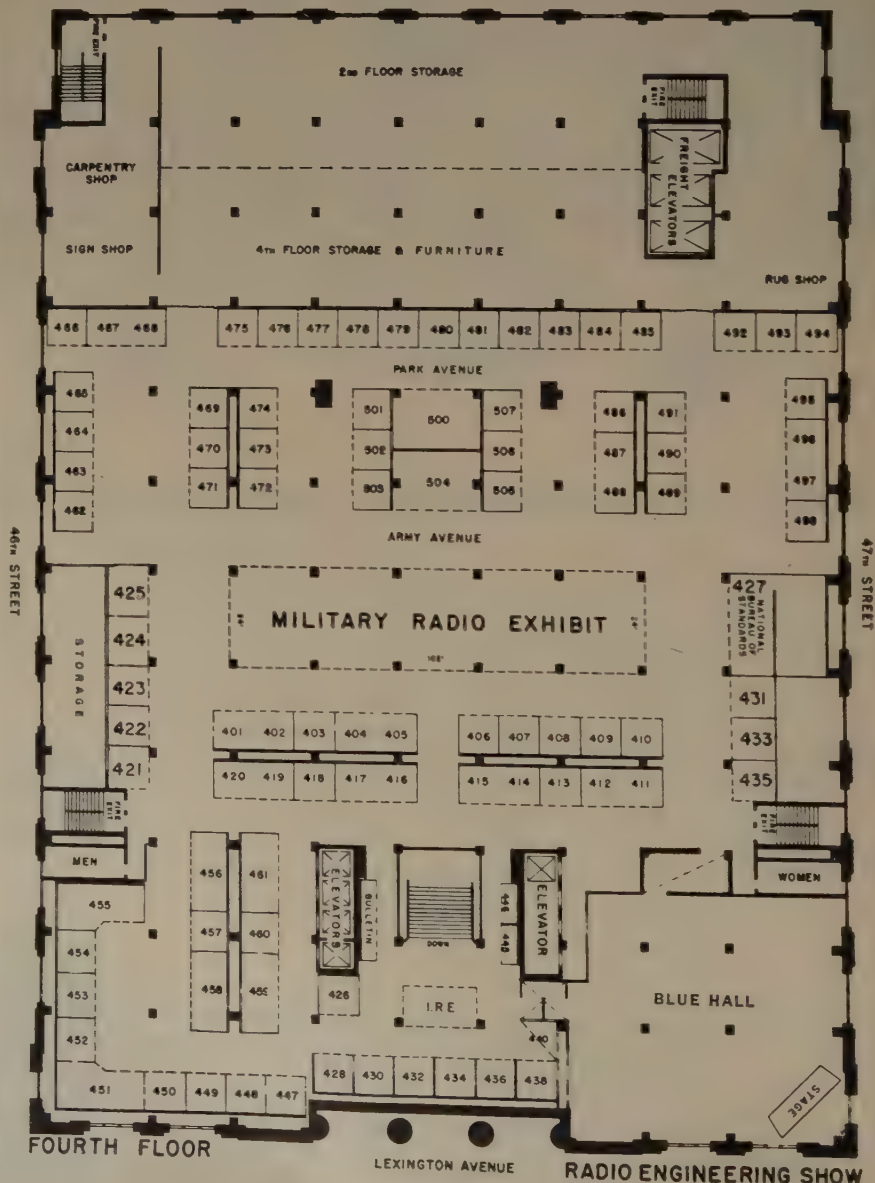
Cleveland 14, Ohio

## What to see at the Radio Engineering Show

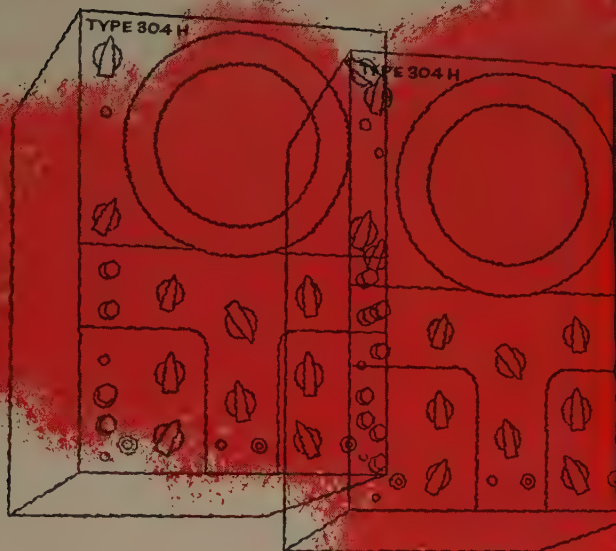
(Continued from page 88A)

Firm	Booth	Firm	Booth
Ethylene Chemical Corp., Summit, N.J.	498	Flying spot scanner, master monitor, sync generator, high quality monitor, low voltage power supply, color sync generator, color flying spot scanner, and color master monitor. Impedometer, all metal traveling wave tubes, traveling wave tubes.	
Teflon insulating material.		Federal Telephone & Radio Corp., Clifton, N.J., Federal Hall	135
Fairchild Camera & Instrument Co., Jamaica 1, L.I., N.Y.	238, 239	Pulse time modulation microwave equipment; transmitting, rectifier, and industrial vacuum tubes; selenium rectifiers and hf cable; mobile radio: vehicular and railroad.	
Precision linear and non-linear potentiometers. Fairchild-Polaroid oscilloscope recording cameras. Oscillo-record (continuous-motion oscilloscope recording) camera.		Federated Metals Div., Amer. Smelting & Refining, New York 5, N.Y.	414, 415
Falstrom Co., Passaic, N.J.	423	Solders and other non-ferrous metals used in the radio and electronics industry.	
Instrument and control panel boards. Aluminum chassis. Miscellaneous fabricated metal parts, including cold rolled steel, stainless steel, and aluminum for the communication, electronics and aviation fields.		Federated Purchaser, Inc., Newark 4, N.J.	473
Fairchild Recording Equipment Corp. Whitestone, L.I., N.Y.	325A	R.C.A.—G.E.—Amphenol—Cornell-Dubilier—Hytron—Altec Lansing—University Loudspeakers—Triplett—Simpson—Weston—Federal Telephone & Radio—Radio Receptor Co.—Ward Leonard—Chicago Transformer—Sola Electric Radiant-Raytheon—Sprague—Centralab—Sangamo—Ohmite—Amperite—Alpha—Beldon—U. S. Engineering—Littlefuse.	
Professional synchronous tape recorders, disk recorders and transcription tables, multi purpose pickups, equalizers, pre-amplifiers, cuing amplifiers, thermostylus kits, control track generators, automatic framing devices, etc.		Ferris Instrument Co., Boonton, N.J.	1-3
Federal Telecommunications Labs., Inc., Nutley 10, N.J., Federal Hall	135	Slotted measuring line, signal generators, microvolts, radio noise and field strength meters, and calibrators.	
VHF Omnidirectional radio range antenna, TV microwave relay link, and VHF airport radio direction finder, airborne distance measuring equipment, TV sound channel equipment. TV equipment:			

(Continued on page 94A)



A general-purpose **DUAL**-beam oscillograph  
to fit your needs technically and financially



# the **DU MONT** **TYPE 322**

Not just another specialized dual-beam oscillograph, but a brand-new type designed for general development work but rugged enough for production testing and industrial applications as well. Compactness, lightweight, ruggedness and versatility mark the Du Mont Type 322 as another milestone in cathode-ray oscillography.

## FEATURES

All the well-known features of the 304-H, and...  
Thoroughly field-tested.

Individual and common time bases with driven or recurrent sweeps and sweep expansion on all sweeps.

Conventional single-ended input with stepped and vernier attenuators, or balanced input with no attenuation, on both Y-axes.

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Illuminated scale with dimmer control.

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Cathode-ray Tube — Type 5SP — Dual-beam Cathode-ray Tube. Accelerating potential, 3000 volts.

Y-Deflection Sensitivity — 0.028 peak-to-peak (0.01 rms) volts/inch from D-C to 300 KC (50% down at 300 KC); A-C coupling, 10% down at 5 c.p.s.

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Linear Time Base — Recurrent and driven sweeps variable in frequency from 2 to 30,000 c.p.s. Front panel connections provided for lower frequency by adding external capacitance.

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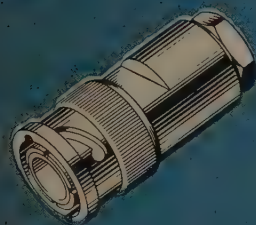
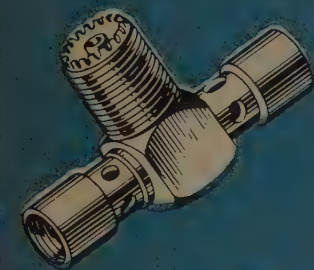
Power Source — 115/230 volts — 50-400 c.p.s. — 225 watts.

Dimensions — Height 15 $\frac{3}{4}$ ", width 12 $\frac{1}{2}$ ", depth 22 $\frac{1}{8}$ ", weight 75 lbs.

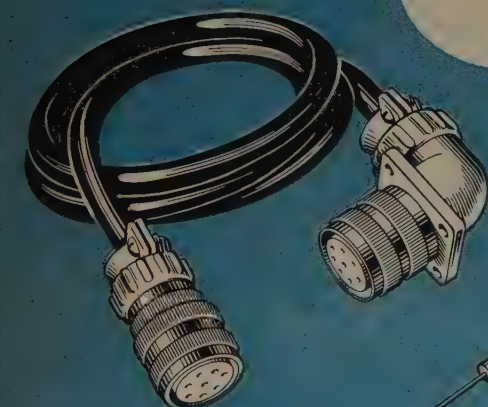
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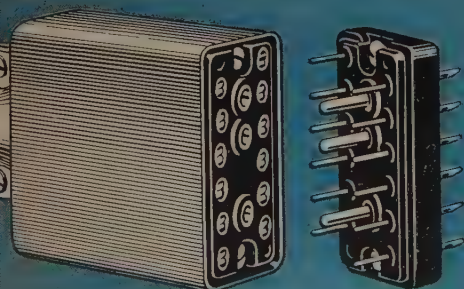
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RF CONNECTORS



SPECIAL A N CABLE HARNESSES



RACK AND PANEL CONNECTORS

# .....Electronic

## COMPONENTS for INDUSTRY

Over 9,000 items to meet every application need!

- RF TRANSMISSION LINES AND CONNECTORS
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- SPECIAL A N CABLE HARNESSES



COAXIAL (POLYETHYLENE) CABLES

## What to see at the Radio Engineering Show

(Continued from page 92A)

- | Firm   | Booth   |
|--|---------|
| The Filtron Co., Inc., Flushing 55, N.Y.   | 45      |
| Miniaturized radio interference suppression filters.   |         |
| Fisher Radio Corp., New York 17, N.Y.  | 314A    |
| High quality receivers and amplifiers, preamplifier, the Concertone tape recorder, and the RJ speaker system.  |         |
| Ford Instrument Co., Div. Sperry Corp., Long Island City 1, N.Y.   | 213     |
| Synchro and servo motors, resolvers, mechanical differentials. Low inertia servo motors with high voltage control windings. Work directly into tubes thus eliminating need for transformer in amplifier.   |         |
| Freed Transformer Co., Inc., Brooklyn 27, N.Y.   | 103     |
| Transformers, reactors, precision laboratory measuring equipment, electric wave filters, high "Q" toroid inductors, pulse transformers.  |         |
| Furst Electronics Chicago 6, Ill.  | 363     |
| Wide-band dc amplifier, wow meter, various regulated power supplies.   |         |
| The Fusite Corp., Cincinnati 13, Ohio  | 360     |
| A complete line of Fusite glass-to-metal terminals for hermetic sealing of all types of electrical components. Exhibit will include Fusite terminals applied to actual products of our customers in the field of electronics, instruments, switches, transformers, and refrigerator compressors.   |         |
| Gates Radio Co., Quincy, Ill.  | 214     |
| Broadcast and television speech input equipment, a vhf 250 watt FM relay transmitter, standard broadcast 1000 watt transmitter. Several assemblies and groups of switching and control apparatus for broadcast and communications systems of various types.  |         |
| General Ceramics & Steatite Corp., Keasbey, N.J.   | 47      |
| Technical ceramics, including steatite, porcelain, titanates, zircon steatite, light duty refractories, end products consisting of insulators, coil forms, switch parts, sockets, connectors, and hermetic seal terminal bushings of the metalized and compression seal types, ferramics (magnetic ferrites). Dielectric materials.  |         |
| General Electric Co., Schenectady 5, & Syracuse, N.Y.  | 113-119 |
| Second harmonic magnetic converter, photoelectric recorder. Capacitors, soldering irons, relays, rectifiers, switches. hono cartridges and diamond styli, speakers tone arms, preamplifiers TV components—Germanium power rectifier, germanium diodes—TV test equip.—oscilloscopes—marker generator—sweep generator power supplies. Tubes, C-R—TV & radio receiving TV picture—uhf rf power, gas switching, uhf and vhf types. |         |
| General Electric Co., Apparatus Div., Schenectady 5, & Syracuse, N.Y.  | 397B    |
| Transformers: MIL-T-27, Permafil, and silicone. Voltage regulators, magnetic amplifier, dry-type high voltage power pack, magnetic current reference.  |         |
| General Precision Laboratory, Inc., Pleasantville, N.Y.  | 18-20   |
| G.P.L. Camera chain, 35 mm TV projector by Simplex, G.P.L. 16 mm projection equipment, completely remotely controlled TV camera.   |         |
| General Radio Co., Cambridge 39, Mass.   | 92, 93  |
| UHF TV Station monitor. UHF Impedance Measuring Equipment. Unit Instruments. Vacuum-Tube bridge, Variac (®) Autotransformers. Sound-Level Meter. Sound-Survey Meter, Sound-Level Calibrator. Octave-Band Analyzer. Sound Analyzer. Vibration meter, Vibration analyzer. Vacuum-Tube Voltmeters. Crystal Voltmeter. Megohmmeters, light meter, output power meters, microvolter, standard-signal generators, coaxial elements.  |         |
| General Transformer Co., Homewood, Ill.  | 449     |
| Transformers—Power audio, reactors, for commercial and military applications. Rectifier power unit and battery charger—PP34. Perma power, ac-dc power supplies to convert battery operated radio sets to 110 v ac line operation.  |         |
| John Gombos Co., Inc., Irvington 11, N.J.  | 263     |
| Tracking switches, dial light sockets, filters, terminator assemblies, beryllium copper connectors, and precision parts used in the electronic industry.   |         |

(Continued on page 95A)

**AMPHENOL**

**AMERICAN PHENOLIC CORPORATION**

1830 SOUTH 54th AVENUE • CHICAGO 50, ILLINOIS

## What to see at the Radio Engineering Show

(Continued from page 94A)

- | Firm  | Booth     |
|---|-----------|
| <b>Grant Pulley &amp; Hardware Co.,</b> Flushing, N.Y.  | 462       |
| Electronic equipment slides—a complete line of slides which enable electronic apparatus (chassis, consoles, racks, etc.) to slide in or out of its casing. Mechanisms available which can tilt unit to any desired angle for servicing. Slides are made for loads up to 2,000 pounds. Complete engineering liaison service available. |           |
| <b>Gray Research &amp; Development Co., Inc.,</b> Hartford 1, Conn.   | S-9, S-10 |
| Industrial color television; Telop, studio TV projector; Multiplexer, studio TV use. Camera turret, studio TV use. Transcription arms & equalizers.   |           |
| <b>Grayhill</b><br>See: Wally Swank   | 221       |
| <b>Green Instrument Co., Inc.,</b> Cambridge 39, Mass.  | 369       |
| Pantograph engraver for name plates, dials and scales. Instrument panels up to 19" in height by any length. Rotary tables, self-centering vices, clamping fixtures, and cutter grinder. Special machinery for production engraving.   |           |
| <b>Guardian Electric Mfg. Co.,</b> Chicago 12, Ill.   | 367, 368  |
| Hermetically sealed relays, AN approved electrical controls, radio relays, and television components.   |           |
| <b>Gulton Mfg. Corp.,</b> Metuchen, N.J.  | 428       |
| Acoustic and electric delay lines, Glennite subminiature capacitors and components, cathode followers and amplifiers, capacitor bridge transducer display (microphones, hydrophones, vibration pickups, ultrasonic transducers, phono pickups) Glennite piezoelectric ceramics.   |           |
| <b>Halderson Co.,</b> Chicago 40, Ill.  | 470       |
| Complete line of transformers and reactors for new construction and replacement purposes. High fidelity transformers for broadcast and music reproducing applications.  |           |
| <b>H. B. Hardman,</b> Belleville, N.J.<br>See: Robinson, Edward   | 479       |
| <b>Harrison Radio Corp.,</b> New York 7, N.Y.   | 323       |
| "Electronic Information Quotient," An automatic device loaned by the U.S.N. to rate a person as to accuracy and speed of response to questions.   |           |
| <b>A. W. Haydon Co.,</b> Waterbury 20, Conn.  | 54        |
| Chronometric governed dc timing motors, time delay relays, and sequence or repeat cycle timers.   |           |
| <b>Helland Research Corp.,</b> Denver 9, Colo.  | 304       |
| Galvanometers, 400 and 500 recorders, 708 table mounted recorder and 708 rack mounted recorder, and 800-1 single channel amplifier.   |           |
| <b>Heldor Mfg. Co.,</b> Bloomfield, N.J.  | S-17      |
| Hermetic seal bushings, weld studs, and MIL-T-27 cans, blind inserts. Bushing assemblies, header assemblies.  |           |
| <b>The Helipot Corp.,</b> S. Pasadena, Calif.   | 84        |
| Precision linear single and multiturn potentiometers and servo controls, turns and position indicating dials, and miniaturized servo controls—linear.   |           |
| <b>Heminway &amp; Bartlett Mfg. Co.,</b> New York 18, N.Y.  | 327       |
| Twisted nylon lacing cords, and flat braided nylon lacing cords.  |           |
| <b>Heppner Mfg. Co.,</b> Round Lake, Ill.   | 321       |
| Loud speakers, horizontal transformers, ion traps, beam centering controls, focus devices, vibration mounts, gun heaters, cable assemblies, rf chokes, ferrite antenna coils, correcting magnets, standpipe connectors.   |           |
| <b>Hermetic Seal Products Co.,</b> Newark 7, N.J.   | 129       |
| Hermetic seals, glass-metal. Hermetically sealed terminals, bushings, headers, plugs and bases, in single terminals or multi-headers for the electronic industry.   |           |
| <b>Hewlett-Packard Co.,</b> Palo Alto, Calif.   | 40, 41    |
| Electronic test and measuring instruments. S24A test set—for gun fire radar testing.  |           |

(Continued on page 122A)

## Components for Industry

TO SOLVE EVERY ELECTRONIC and POWER PROBLEM!

*Radio-Electronic Engineers!* You'll find your friends and associates at the Amphenol Display Booth — meet them there!

VISIT

**AMPHENOL**

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GRAND CENTRAL PALACE • MARCH 3, 4, 5

BOOTHS 111-112

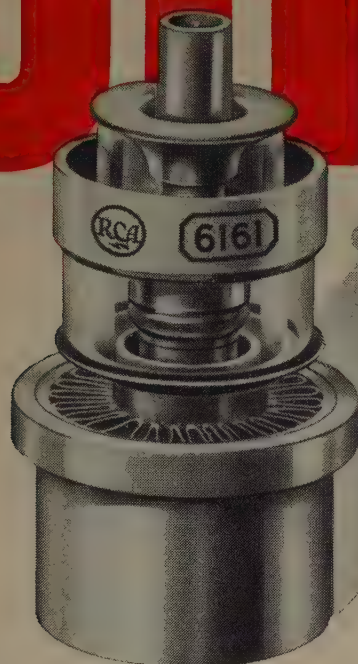
Most of the Amphenol electronic components — and there are over 9,000 of them — are the direct result of a specific application problem arising in industry. Users of Amphenol components know that when they bring their electronic and power application needs to Amphenol they are availing themselves of one of the most specialized engineering staffs and testing laboratories in the electronics industry.

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# UHF-TV



## TYPICAL TV POWER AMPLIFIER OPERATING CONDITIONS

Grounded-Grid Circuit, at 900 Mc, with  
6.0 Mc. Band Width for Class B and  
Grid-Modulated Class C Service

DC Plate Voltage	1500 volts
Peak RF Grid Voltage	135 volts
DC Plate Current	
Synchronizing Level	0.350 amp.
DC Grid Current	
Synchronizing Level	0.030 amp.
Driver Power Output (Approx.)	
Synchronizing Level	75* watts
Output Circuit Efficiency	65%
Useful Power Output	
Synchronizing Level	230† watts

\*This value includes 28 watts of RF circuit loss and 40 watts of RF power added to the plate input.

†This value of useful power is measured at load of output circuit having indicated efficiency.

## *Another RCA First...* **RCA-6161 forced-air cooled power triode for UHF services up to 2000 Mc.**

Featuring forced-air cooling, and a coaxial-electrode structure, the new RCA-6161 is particularly suited to grounded-grid operation in circuits of the coaxial-cylinder type. In addition to its use as a power amplifier in UHF television transmitters, the RCA-6161 may be employed as an RF amplifier or frequency multiplier in Class C telegraphy and telephony at frequencies up to 2000 Mc.

The RCA-6161 has a maximum plate dissipation of 250 watts in CW or TV applications, and can be operated at full plate voltage and plate input at frequencies as

high as 900 Mc...and at reduced ratings up to 2000 Mc.

The RCA-6161 is of the heater-cathode type, the heater drawing 3.4 amperes at 6.3 volts. The coaxial-electrode structure provides low inductance, large-area RF electrode terminals, and permits effective isolation of plate and cathode.

For complete technical data on the RCA-6161, write RCA, Commercial Engineering, Section BR47, Harrison, N. J., or your nearest RCA field office.

**FIELD OFFICES:** (East) Humboldt 5-3900, 415 S. 5th St., Harrison, N. J. (Midwest) Whitehall 4-2900, 589 E. Illinois St., Chicago, Ill. (West) Madison 9-3671, 420 S. San Pedro St., Los Angeles, Calif.

## *Another* new RCA tube

RCA-6080 Twin Power Triode, intended for use as a regulator tube in dc power supplies. Similar to 6AS7-G, but with improved resistance to shock and vibration.



THE FOUNTAINHEAD OF MODERN TUBE DEVELOPMENT IS RCA



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# PROCEEDINGS OF THE I.R.E.

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## Harold L. Kirke

VICE-PRESIDENT, 1952-

Harold L. Kirke was born on January 7, 1895, in London, England. He received army wireless training, and during World War I, he served as a radio instructor to officers classes in the British Army Signal schools. From 1920-1924, he was with the Marconi Wireless Company experimental section, and was an important member of a group that built and operated the Writtle Broadcasting Station. In 1924, Mr. Kirke joined the British Broadcasting Corporation as a development engineer, and in 1925, he became the head of the development department. This section later became the research department. Mr. Kirke is now the Assistant Chief Engineer of BBC.

Mr. Kirke was the chairman of the radio section of the Institution of Electrical Engineers from 1944-1945, and was also a member of the council of that body. In June, 1947, he was made a Commander of the Order of the British Empire. He is the chairman of the Acoustics Group of the Physical Society, and a member of the Physical Society Council.

Becoming a Member of the IRE in 1925, Mr. Kirke was elevated to Senior Member in 1943, and was presented the IRE Fellow Award in 1945, for "services to broadcasting in the British Isles and in particular for his leadership in the research activities of the British Broadcasting Corporation."

# What Are We Going to Use for Engineers?

R. D. BENNETT

In the early days of American life, the scope and functions of government were relatively restricted and simple. The more complex industrialized system of today has brought a vast expansion in the scope of governmental operations, and has correspondingly increased their individual complexity and their interrelationships. This change, in turn, has imposed great burdens and responsibilities on government officials and has made serious demands on their skill, experience, and ingenuity.

One of the resulting technical problems, which is of basic significance to the people of all modern countries, is clearly and constructively analyzed in the following guest editorial from the Technical Director of the United States Naval Ordnance Laboratory at Silver Spring, Maryland. The author is a Fellow of the IRE.—*The Editor.*

Those of us who have responsibilities, whose successful discharge depends on a continuing supply of young engineers, view with great concern the disparity between the engineering work load we expect and the supply of talent likely to be available.

Last year's crop, while not the highest on record, was a bumper one, yet the demand was at least twice the supply. The average for the next five years will be about half those available in 1951. While demand in research and development may taper off in a year or two, the increased need in production may easily offset any such decrease. Out of the relatively meager supply of engineers available, the armed forces may be expected to take the substantial fraction who have been trained under ROTC auspices, and unless we formulate policies to the contrary, some additional ones will be taken through selective service.

Therefore, we find ourselves in a position where our technical output is limited by our trained engineering manpower. Unless we husband this trained manpower with care, this output may be too low for us to meet successfully the challenge we face. What can we do?

It seems clear that there will be no easy solution to this problem; however, a co-operative effort on the part of all hands may yield an adequate answer.

First, we can choose between what we would like to have and what we really need.

Secondly, we can simplify some of the military "gadgets" we are building.

Thirdly, we can curtail, temporarily, our demands for less essential goods and services.

Next, we can make better use of the engineers we do have. This means we must cease hoarding for hoped-for contracts; improve our management of engineering talent; extend our work week; fleet up subengineering talent; separate and segregate the less difficult parts of our engineering jobs and get them done by less extensively trained people; get engineers in the armed services into jobs which use their engineering talent.

Then, we can intensify our on-the-job training of engineers or potential engineers. We can expand opportunities for undergraduate as well as advanced academic training. We can teach relatively untrained people to do specific jobs, and we can train management to generate better teamwork.

Finally, we must broaden the base of our engineering manpower structure. To do this we need to get less shadow and more substance into the secondary school training of those who have the wit to absorb it. We must encourage more women to enter the profession. We must be more vocal in demonstrating that engineering training is a good basis for almost any calling, and we may have to adjust the relative financial rewards of engineers so that it does not take ten years for the engineer to catch up economically with his fellow high school graduate who took up a trade.

We can prosecute all these approaches to the solution of our problem. If we prosecute them with vigor, we can haul ourselves out of a tight situation. If we do not, we shall not only fail in our effort to have both guns and butter; we can also expect our troubles to multiply and our security to be seriously jeopardized.

# Admissions and Transfers\*

RAYMOND F. GUY†, FELLOW, IRE

THE BEST INTERESTS of our profession are served by having a strong, efficient, and smoothly functioning society such as our IRE. The high esprit de corps and the pride in membership in our Institute are a reflection of many tangible and intangible factors including, through regional representation, the opportunity to participate in the formulation of policies and practices, candid and frequent discussion of Institute problems, and the maintenance of high professional standards.

As in all professional societies, the IRE has various membership grades which reflect the professional competence, experience, and character of the individual, and his standing in his chosen profession. The grade of Student Member provides for membership by engineering undergraduates. The grade of Associate provides an avenue through which nonprofessional people may become members of the Institute, without voting and certain other privileges. The grade of Member denotes professional experience and competence, and provides for professional recognition of qualified young men early in their careers, or others of as yet limited professional ability. The grade of Senior Member recognizes and denotes high professional competence, extended experience, and the ability to assume major responsibility in the practice of one's profession. And the grade of Fellow is an honor conferred by the Board of Directors for outstanding contributions to the science or technology of radio and allied fields. All members are encouraged to aspire to the highest grade for which they are qualified, and to take pride in the professional competence which it denotes.

Our members are entitled to have the stature of the membership grades maintained, and applications for admissions and transfers handled smoothly, fairly, and promptly. Your officers, directors, committees, and headquarters staff make every effort toward that end. The Admissions Committee is a hardworking and conscientious group, presently under the chairmanship of Mr. H. P. Corwith. The Membership Committee, currently under the chairmanship of Mr. Ringland Krueger, is deeply concerned with encouraging membership among qualified nonmembers, upgrading qualified members, and analyzing the reason for resignations and minimizing them. And the Public Relations Committee, now under the chairmanship of Mr. Lewis Winner, is developing the program by which the Institute and the accomplishments of its members are brought to the attention of their employers, the industry, and the public.

These Committees have as their functions the maintenance of the stature of the membership grades; enhancement of knowledge and pride in what they represent; encouragement of qualified nonmembers to

seek membership and of qualified members to advance their grades; prompt, impartial, fair, and helpful action on membership applications; the maintenance of satisfactory public relations; and enlightenment of the public, the industry, and others concerning the accomplishments and activities of our members, the Institute, and the profession.

It is believed particularly timely to familiarize members of the Institute with the manner in which admissions and transfers are handled, and to solicit their co-operation in overcoming some of the difficulties which add to the burden of the Admissions Committee, the headquarters staff, some of your officers, and new applicants.

Applications for admission or transfer go through a routine which has been modified at intervals in an attempt not only to reduce the time of processing, but also to insure the utmost fairness to the applicant. Until recently applications for admission or transfer, upon receipt, were processed in the following order:

1. They went to the File Department to determine if the applicant had formerly been a member of the Institute.

2. If not, they were sent to the Applications Department, where the reference forms were mailed to those listed by the applicant.

3. The application and the returned reference forms were sent to the File Department to determine whether the references were qualified under the bylaws.

4. The application, reference forms, and other pertinent information were transmitted to the Admissions Committee for consideration.

5. The Admissions Committee, meeting monthly, recommended either that the application be approved, that additional information or qualified sponsors be sought through the applicant, that no affirmative action be taken because the applicant was not qualified, or that a suggestion be made to the applicant that he accept a lower grade of membership consistent with his qualifications.

6. Applications recommended for approval are transmitted to the Executive Committee for final action. Applications not recommended for approval go to the Membership Relations Co-ordinator for review and any special action deemed advisable in collaboration with the Admissions Committee and the Executive Committee. The Membership Relations Co-ordinator is a member of the IRE Executive Committee, and is responsible to it for activities of the Membership, Admissions, and Public Relations Committees.

Although many applications were received without adequate qualified references, they nevertheless were forwarded to the Admissions Committee because, in some cases, it had been found that the applicants were so obviously qualified that the reference requirements could be waived in part. However, the number of such applications lacking the required number of qualified references has become so large that the

processing routine has been modified. Under the new routine, applications from the United States and Canada having insufficient qualified references are held at headquarters while the applicant is requested to complete the quota. They are then processed as formerly. Applications outside of the United States and Canada are processed under the old routine. The reason for the difference lies in the fact that most of the applications are from the United States and Canada, little time is consumed in corresponding with applicants, and in most localities qualified references may be found. On the other hand, in foreign countries there are relatively few applicants, correspondence requires a relatively long time, and qualified references are relatively few in number.

Every practical step has been taken to expedite favorable action on applications when the applicant is qualified and when he has provided the information and list of qualified references as specified in the Institute bylaws. Consideration of an application must, of course, be based upon the information contained in the file of correspondence.

In the processing of applications and transfers, two difficulties recur which delay action and unnecessarily add to the work load of the office staff and your fellow members who contribute their time and effort in committee to serve you. One of the most troublesome delays in the admissions or transfer processing arises because too often the references given are either nonmembers of the Institute, or they are not of the required membership grade. It is found frequently that only one or two of the references comply with the membership-grade requirements for references, and at times none do.

The Institute bylaws and membership literature specify exactly, and in the most simple terms, that on an application for Associate Grade, at least three references of Associate or higher grade are required; for Member, at least four of Member Grade or higher are required; and for Senior Member, at least five of Senior Member or Fellow are required. Compliance with these simple requirements ordinarily is not difficult. But if assistance is desirable in seeking qualified references, it is recommended that the applicant attend one or more of his local IRE Section meetings and obtain the assistance of the officers, which will be given gladly. If it is not feasible to attend a Section meeting, one may obtain assistance from IRE headquarters, or from among those qualified references to whom one is known. If these avenues are not available, discretion will be exercised in accepting references from members of other scientific societies in related fields, provided that they hold comparable grade in those societies. It is also possible to exercise discretion in difficult cases where one of the references who is a nonmember of IRE is the applicant's supervisor and is familiar with his work.

The Admissions Committee seeks to be helpful and constructive and to aid appli-

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cants. But as your guardian in the maintenance of member grade standards and stature, they have no choice but to withhold favorable action if the applicant is not qualified or if he has neglected to comply with the requirements laid down in the by-laws.

In preparing applications, all too frequently the applicant neglects to submit sufficient information to substantiate the experience or other qualifications which he has claimed. It is helpful for an applicant to bear in mind in preparing applications that the Admissions Committee will know only what he submits to them, and must judge his work largely upon the description he he provides. The comments of his references are relied upon to substantiate his claims and not, in general, to add further details. An applicant should recognize that he has an obligation to comply with the bylaws of an organization in which he seeks membership or upgrading, and he should perceive that the processing of his application would be facilitated if he complied as completely as possible.

It would be helpful for applicants, insofar as possible, to select references to verify his entire experience, rather than having all of them selected to verify only the last year or two. This in itself may make it easier to find references, particularly if the applicant has recently transferred to new employment and has not yet established many new acquaintances.

The second main difficulty arises because persons receiving reference forms, for vari-

ous reasons, do not reply, or do not do so promptly. Frequently, this is found when the person to whom it was referred feels that he does not know the applicant, does not know enough about him, or is reluctant to recommend a denial of the application. In such cases, it is necessary for the headquarters group to follow up the original reference with further correspondence, pointing out that the application remains dormant until the necessary number of references have been heard from.

It is urged that those receiving reference forms return them promptly with their recommendations or, if they prefer not to make recommendations, so to indicate in order that other references may be used or sought. In fairness to the applicant and others involved, those named as references should inform headquarters of their wishes in the matter. Indefinite delay in returning reference forms may prejudice unfairly the ultimate outcome of an application, whereas prompt return with a note that the applicant is unknown or not well enough known will not influence the action taken.

A large proportion of new applications for membership are stimulated by association with IRE members, and many of the applications for transfer are stimulated by the Sections Committee or officers. It is urged that, where possible, members of the Institute should aid new applicants in filling out their forms so as to insure that experience is properly specified, at least the minimum number of qualified references is named, and that the forms are complete and

properly addressed. In so doing you can be of great assistance in eliminating a duplication of work and much loss of time, and you will also help prevent loss of membership on the part of applicants who become irritated or discouraged by extended correspondence, requests for more names, and the like. And it is urged that members applying for upgrading facilitate the prompt processing of their applications by specifying at least the minimum number of qualified references and providing complete information. Those charged with responsibility for approving or denying requests for admission or transfer have for their guidance a manual which has been developed and improved through the years. It has insured consistency and uniformity of action, and maintenance of the stature of the grades. You are urged, in preparing applications, to keep in mind that an applicant's qualifications must be judged by the information contained in the written material presented for consideration, which normally consists of the applicant's own statements and the recommendations and comments of his qualified references.

It is recommended that applicants provide their references with a summary of their technical training and experience because, frequently, those named as references have an incomplete recollection of an applicant's professional history. In the absence of such recollection, the persons named as references must request it, or restrict their comments, to the possible disadvantage of the applicant.

## The Application of Damping to Phonograph Reproducer Arms\*

WILLIAM S. BACHMAN†

This paper is published with the approval of the IRE Professional Group on Audio, and has been secured through the co-operation of that Group.—*The Editor.*

**Summary**—Large forces are developed at the stylus tip of a conventional phonograph reproducer arm because of excitation of the resonance of the arm mass with the suspension compliance. This paper presents an analysis of the problem and describes a reproducer-arm design in which mechanical resistance is introduced in the pivots. By this means, control of the arm resonance is obtained without increasing the stylus-tip impedance of the reproducer.

THE STYLUS-BEARING force of a disk reproducer upon the record must be small to limit the bearing pressure to reasonable values. This low force is called upon to hold the stylus in contact with

the groove against the dynamic forces developed at the stylus point at arm resonance, and to move the reproducer arm about its vertical pivot along the spiral path which the record groove presents. By providing damping in both the horizontal and vertical pivots, this resonant force is greatly reduced, improved resistance to external shock is obtained, and protection against damage from accidental release of the reproducer head is achieved.

At low frequencies, say below 500 cps, the mechanical system of a phonograph reproducer arm and pickup cartridge may be represented by a mass suspended on a spring. In Fig. 1(a) (see following page),  $m$  represents the effective mass of the arm and cartridge assembly, referred to the stylus point. This is always less than

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the weight of the assembly since it is partly supported at the far end by the pivot about which it rotates. The compliance (the reciprocal of stiffness) of the stylus suspension is represented by  $c$ .

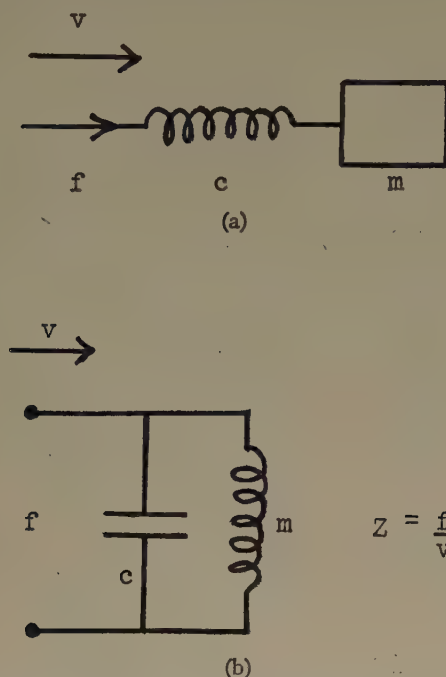


Fig. 1—(a) Mechanical schematic diagram of a conventional reproducer arm and cartridge at low frequencies.  
 $c$  = the needle-suspension compliance of the reproducer cartridge  
 $m$  = the effective mass of the arm and cartridge assembly, referred to the stylus tip  
 $f$  = the force developed at the stylus tip  
 $v$  = the velocity of motion of the stylus tip.  
 (b) Electrical equivalent of mechanical system of 1(a).  
 $Z$  = the mechanical impedance at the stylus tip.

Below the resonant frequency of the system, which is often in the 30-to-60-cps region, the motion of the mass corresponds to the motion of the driving point. In other words, the arm and cartridge follow the slow progress of the spiral groove. Above the resonance, the system becomes mass controlled, and the arm does not follow the rapid undulations which the modulated groove imposes upon the reproducer stylus. This difference in motion between the stylus and the arm provides the stimulation of the pickup, to which the output voltage is proportional.

The operation of the system may also be described in electrical terms by referring to the analogous circuit in Fig. 1(b). The mass is analogous to inductance, compliance to capacitance, force to voltage, and velocity to current. The unidirectional motion which describes the radial motion of the arm in following the spiral groove corresponds to dc in the electrical system. The alternating velocity imparted to the stylus by the groove modulation corresponds to ac in the electrical network. Above the resonant frequency this velocity (or current) divides between the compliance,  $c$ , and mass,  $m$ , practically all of it admitted by the compliance in the useful range of the reproducer. The output voltage is proportional to the velocity to which the compliance is subjected in a magnetic type of reproducer, or to the in-

tegral of this velocity in a displacement-sensitive reproducer.

At the resonant frequency of the circuit of Fig. 1(b), the impedance,  $Z$ , reaches very high values, limited only by the  $Q$  of the system. The  $Q$  of the mass element is very high. There is usually some dissipation in the suspension compliance, however, but its value must be limited if the mid-range impedance of the system is not to be made too high.

To indicate schematically where the dissipative element appears, the mechanical system is shown in Fig. 2(a). This mechanical system schematic shows that deflection of the suspension spring is accompanied by work done in the friction or mechanical resistance element  $r$ .

The electrical equivalent of this mechanical system is shown in Fig. 2(b).

As a practical example, let us assume a suspension compliance of  $10^{-6}$  cm/dyne and an effective arm mass, referred to the stylus tip, of 20 grams. These are in the range likely to be encountered in actual practice. Such an arm and cartridge assembly would have an arm resonance frequency of

$$f = \frac{1}{\sqrt{4\pi^2 mc}} \frac{1}{\sqrt{4\pi^2 \times 20 \times 10^{-6}}} = 35.6 \text{ cps.}$$

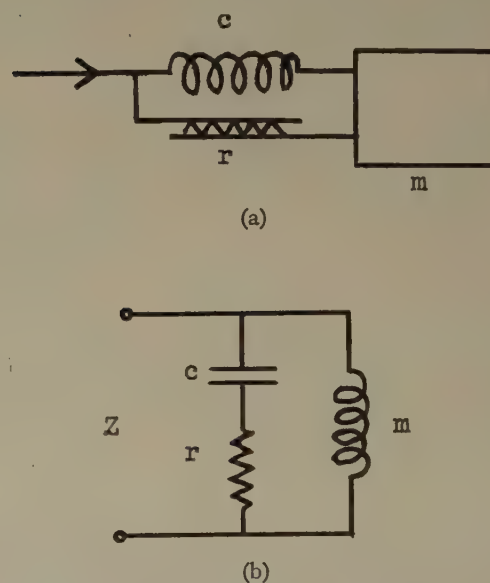


Fig. 2—(a) Mechanical schematic of phonograph reproducer arm and cartridge, with damping in the needle suspension.  
 $r$  = the effective mechanical resistance resulting from the dissipation in the needle suspension. (b) Electrical equivalent of mechanical schematic in (a). Above resonance the impedance at the needle point  $Z$  can never become lower than  $r$ .

To critically damp this resonance, the value of  $r$  would have to be

$$r = \sqrt{\frac{4m}{c}} = \sqrt{\frac{4 \times 20}{10^{-6}}} = 8,950 \frac{\text{dyne sec}}{\text{cm}} \text{ (mech. ohms).}$$

Now, inspection of the circuit in Fig. 2(b) shows that, above the resonant frequency, the impedance approaches  $r$ . ( $X_m$  gets very large and  $X_c$  gets very small.) Suppose that a velocity of 5 cm/sec rms were imposed upon the stylus. This velocity is considerably below the peak program level encountered in most records. The force at the needle point would be

$$f = rv = 9,850 \frac{\text{dyne sec}}{\text{cm}} \times 5 \frac{\text{cm}}{\text{sec}} \\ = 44,600 \text{ dynes or } 45.5 \text{ grams.}$$

If the included angle of the groove were  $90^\circ$ , the upward component of this lateral force would be equal to it, and the needle-bearing force would have to be in excess of  $45.5x\sqrt{2}$  grams (45.5 is the rms value) to insure contact with both sidewalls of the groove. Such a value of needle force is absurd, particularly for micro-groove records, so it becomes obvious that effective damping of the arm resonance cannot practically be obtained by this method.

It has been usual practice to increase arm mass to move the resonant frequency farther below the desired transmission band. This reduces the incidence of arm-resonance excitation by program material, but the resonant impedance is thereby increased, which further increases the susceptibility to jumping as a result of accidental mechanical shock.

If, in the circuit of Fig. 2(b), the resistive element were inserted in series with the mass element, as shown in Fig. 3(a), it would not affect the driving-point impedance of the system above the resonant frequency. In other words, the impedance above resonance of the circuit of Fig. 3(a) would be the same as that of Fig. 1(b), namely, approaching  $X_c$ .

Mechanically, Fig. 3(a) is represented by Fig. 3(b). The proper functioning of the system in the useful signal frequency range, as mentioned before, depends upon all of the imposed motion,  $v$ , being accommodated by the spring,  $c$ . Only below the resonant frequency is the motion of  $m$  significant. Putting the resistance in this position does mean that it will have to "carry the dc," or, in other words, to accommodate the motion imposed by the slow radial progress of the spiral. The velocity of this spiral is quite low. Suppose the record is turning at 78 rpm, with a spiral pitch of 100 lines to the inch. The radial velocity will be

$$v = \frac{1 \text{ in}}{100 \text{ rev}} \times \frac{78 \text{ rev}}{\text{min}} \times \frac{\text{min}}{60 \text{ sec}} = 1.3 \times 10^{-2} \text{ in/sec} \\ \text{or } 3.3 \times 10^{-2} \text{ cm/sec.}$$

The force necessary to move the arm at this velocity against resistance  $r$  is

$$f = rv = 8,950 \times 3.3 \times 10^{-2} = 295 \text{ dynes or } 0.3 \text{ gram.}$$

This is a satisfactorily low value, and furthermore, it is still lower with fine groove records turning at lower speeds.

From the mechanical schematic in Fig. 3(b), it is seen that the mechanical resistance element must be installed between the arm and the motorboard. It could be applied against any part of the arm, or at its pivots,

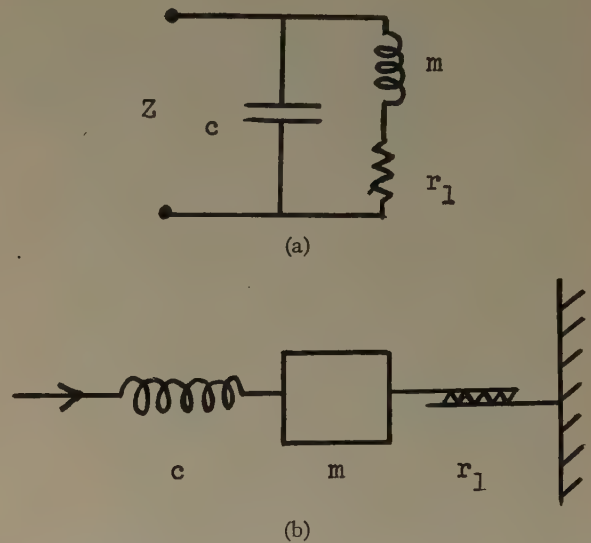


Fig. 3—(a) Modification of the circuit in section (b), which avoids raising the input impedance above resonance without sacrificing the effect of  $r$  upon damping.  $r_1$  is a new circuit element, and not the resistance due to damping in the suspension compliance. (b) Mechanical schematic of electrical circuit of section (a).  $r$  must be inserted between the arm mass and the record or motorboard.

in a wide variety of forms. The idea of some friction connection in the pivots, or elsewhere, is violently opposed to the usual concept of a reproducer arm. In fact, failure of many arms to operate satisfactorily at the low bearing forces which LP microgroove records impose can be traced to excessive pivot friction. This friction is quite different from the desired mechanical resistance. It is true that friction causes energy to be dissipated as heat, as does mechanical resistance. The big difference is that pure mechanical resistance does not change in value as the velocity is varied. In ordinary rubbing friction, the resistance offered varies violently with the imposed velocity. A good familiar example is the large difference between starting friction and running friction, which is observed in bearings. As an example of linear mechanical resistance, consider a boat, floating in water. The resistance it offers is easily demonstrated by the work the engine has to do to move it at constant speed through still water and dead air. Yet this same boat may be moved, slowly, to be sure, with a surprisingly small force in still water and dead air. In this example, the friction of the boat moving through the water is linear, assuming that the velocity range does not extend into turbulence of the water. The friction behaves as a true mechanical resistance, in which the velocity of motion is proportional to the applied force.

While friction is one of the most severe restraints in the design of many mechanical systems, it is almost paradoxical that linear mechanical resistance is very

difficult to obtain. Probably the purest form of mechanical resistance is that which obtains from the motion of a short-circuited conductor in a uniform magnetic field. This is "pure" only in the sense that it is linear. It cannot be separated from the mass of the conductor through which it is developed.

It is possible to compute the amount of mechanical resistance which a given conductor will develop in a magnetic field by using the two basic relations pertaining to a moving conductor in a uniform magnetic field, viz.,

$$f = Bli \quad (1)$$

$$e = Blv, \quad (2)$$

where

$f$  = the mechanical force

$b$  = the flux density

$l$  = the length of the conductor

$i$  = the current in the conductor

$e$  = the voltage induced in the conductor

$v$  = the velocity of motion of the conductor.

Now,

$$r = \frac{f}{v} = \text{mechanical resistance.} \quad (3)$$

Substituting (1) and (2) in (3),

$$r = \frac{B^2 l^2 i}{e} = \frac{B^2 l^2}{R}, \quad (4)$$

where  $R$  is the electrical resistance of the conductor.

Now,

$$R = \frac{\rho l}{A}, \quad (5)$$

where

$\rho$  = specific resistivity of the conductor

$l$  = length of conductor

$A$  = cross sectional area of conductor.

Substituting (3) in (4),

$$r = \frac{B^2 l A}{\rho} = \frac{B^2 V}{\rho} = \frac{B^2 M}{\rho d}, \quad (6)$$

where

$V$  = volume of conductor

$M$  = mass of conductor

$d$  = density of conductor material.

The ratio  $M/r$  has the dimension time and is analogous to the time constant  $L/R$  of an electrical circuit comprising these elements.

Solving (6) for the time constant:

$$\frac{M}{r} = \frac{\rho d}{B^2}.$$

Assuming a copper ring type of conductor in an annular air gap having a flux density of 10,000 lines per square centimeter,

$$\begin{aligned} \frac{M}{r} &= \frac{1.6 \times 10^{-6} \text{ ohm cm}}{1} \times \frac{8.9 \text{ gram}}{\text{cm}^3} \times \frac{\text{cm}^4}{10^{-8} \text{ volt}^2 \text{ sec}^2} \\ \frac{M}{r} &= 14.2 \times 10^2 \frac{\text{ohm cm}^2 \text{ gm}}{\text{volt}^2 \text{ sec}^2} \times \frac{\text{dyne sec}^2}{\text{gram cm}} \\ &\times \frac{\text{volt}^2}{\text{watt ohm}} \times \frac{\text{watt sec}}{\text{joule}} \times \frac{\text{erg}}{\text{dyne cm}} \times \frac{\text{joule}}{10^7 \text{ erg}} \\ &= 142 \times 10^{-6} \text{ sec.} \end{aligned}$$

If the size of conductor were chosen so that 100 mechanical ohms would be developed, the mass of the conducting ring would be

$$\begin{aligned} M &= \frac{M}{r} \times r = 142 \times 10^{-6} \text{ sec} \times \frac{100 \text{ dyne sec}}{\text{cm}} \\ &= 14.2 \times 10^{-3} \text{ gram.} \end{aligned}$$

The presence of mass with the resistance in this mechanical system is analogous to the presence of inductance in an electrical resistor. A resistor of 100 ohms having 14.2 millihenries built in would be far from a noninductive resistor.

Another, more attractive, method of obtaining linear mechanical resistance is through the use of viscous liquids. The resistance may be obtained by moving an impeller through a liquid, forcing the liquid through an orifice, or utilizing the viscous fluid as a film in shear. One difficulty to which these methods are subject is the change of viscosity with temperature. While this effect is large with most petroleum oils, the effect is much smaller in silicone oils. Since the specific value of the mechanical resistance is not critical in this application, either type of oil may be used over a reasonable temperature range.

In Fig. 4, a cross-sectional view of a design using a fluid film in shear is shown. The two concentric surfaces which bound the film are those of a ball and socket. The ball is part of the arm and the socket part of the mounting base. The arm is suspended on the point of a stud which is part of the base. This point is

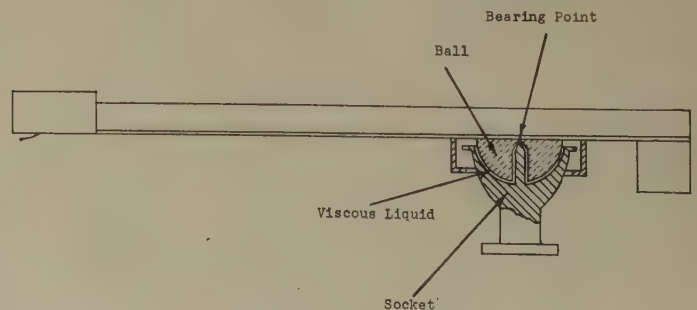


Fig. 4—Cross-sectional view of phonograph reproducer arm having viscous film damped pivot.

at the center of both the ball and socket, and above the center of gravity of the arm. A clearance of about 0.006 inch is maintained between the surfaces of the two spherical segments, and this space is filled with high-viscosity oil (having a viscosity of approximately 50,000 centistokes).

It is evident that this design provides mechanical resistance in both the lateral and vertical planes. While the theoretical analysis of the mechanical system at the beginning of this paper treated only the conditions obtaining in the horizontal plane, it is obvious that a resonance in the vertical plane will also be observed. This may or may not occur at the same frequency as the lateral resonance, depending upon the ratio of vertical to lateral compliance and the effective mass at the stylus tip in the two planes. Usually the vertical resonance is near the lateral resonance so that, substantially, the same value of mechanical resistance is required for its damping. Having damping in the vertical plane also provides protection from damage due to accidental release of the arm. The rate of fall is held to a low value so that the shock of contact is small and no bouncing results. For a reproducer having a needle force of 5 grams, and a damping resistance of 8,950 mechanical ohms, the rate of descent will be

$$V = \frac{f}{r} = \frac{5 \times 10^3 \text{ dyne cm}}{9 \times 10^3 \text{ dyne sec}} = 0.55 \text{ cm/sec.}$$

A similar retarding effect is obtained in the lateral plane which increases the resistance to lateral shock. To put it another way, the tendency of a reproducer arm to function as a seismograph is arrested.

The mechanical resistance obtained by fluid films is proportional to the area of the film and approximately inversely proportional to the film thickness. It has been observed that with thicker films and higher viscosity liquids a significant amount of compliance appears along with the resistance. If this compliance were too large, it would serve to uncouple the resistance element from the system. Small values of compliance, on the other hand, are helpful in that they permit the arm to follow severely warped or eccentric records readily.

It is interesting that the amount of mechanical resistance used in this reproducer arm is not a critical value. The upper limit of resistance is reached when it interferes with tracking records having reasonably small values of eccentricity or warpage. With the usual values of suspension compliance and mass, this would occur at several times the amount of resistance necessary to critically damp the arm resonance. At the other extreme, where the resistance approaches zero, the arm merely reverts to a conventional one, in which there is very low pivot friction. If the design is such that the resonance of the arm and suspension compliance occurs below the desired transmission band, the variation in resonant response, resulting from change in the mechanical resistance, is of little importance. Between these extremes, a wide range of improved performance exists. Even a resistance in the order of one-sixth of the critical value will cut the  $Q$  of the resonant system significantly, with a corresponding improvement in stability as a result.

Fig. 5 shows the performance of an experimental arm similar to the one shown in Fig. 4. A light arm, having

approximately 20-grams effective mass at the stylus tip, was used with a crystal cartridge whose compliance was approximately  $.5 \times 10^{-6}$  cm/dyne. The light arm and stiff cartridge were chosen so that the resonant

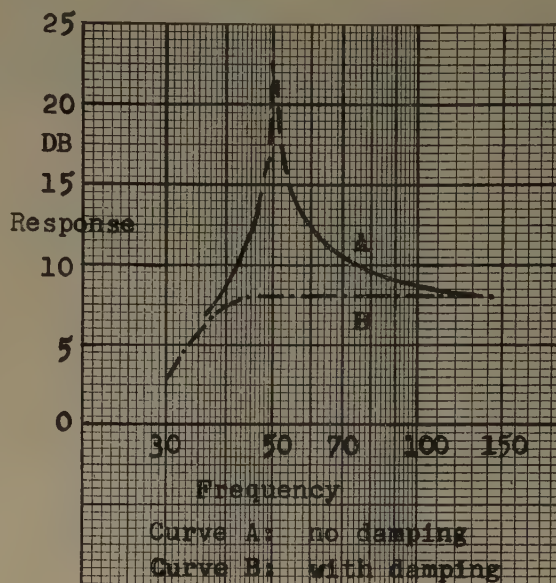


Fig. 5—Response of experimental arm with and without damping.

frequency would be high enough to avoid errors due to pointer vibration in the indicating instruments.

Without damping, the dynamic forces developed near resonance were so large that the stylus was forced out of the groove. For this reason it was not possible to measure the true resonant rise, and the curve therefore shows, with dashed lines, an estimated response in this region.

Fig. 6 is a photograph of a commercial design of a reproducer arm based upon the principle illustrated in

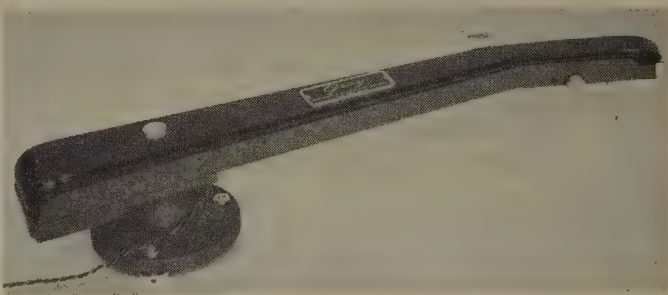


Fig. 6—Photograph of commercial design of a viscous damped reproducer arm.

Fig. 4. In this arm, the thumb screw over the pivot point permits adjustment of the film thickness to accommodate a wide range of temperature.

The application of linear mechanical resistance to the pivots of a phonograph reproducer arm provides effective means for damping the low-frequency arm resonance. When this resonance is brought under control, it is no longer necessary to have a large excess of needle force on the record over that required to follow the desired modulation of the groove.

# Retarding-Field Oscillators\*

J. J. EBERS†, ASSOCIATE, IRE

**Summary**—Pendulum and velocity-variation types of oscillations in retarding-field oscillators are discussed. The processes of bunching, drifting, and working of the electrons are explained, and a comparison is made to a reflex klystron. Recent results obtained from retarding-field oscillators are given.

## INTRODUCTION

POSITIVE-GRID or retarding-field oscillators are among the oldest generators of radio-frequency power. Considerable confusion exists in the literature in regard to the energy conversion mechanism responsible for the oscillations. It is the purpose of this paper to clarify the electron mechanisms involved, as well as to investigate the possibility of the application of such mechanisms to wide-range, high-frequency generators in the 3,000 to 30,000 mc range.

## BARKHAUSEN-KURZ OSCILLATIONS

The original oscillations described by Barkhausen and Kurz<sup>1</sup> are dependent upon a pendulum-like oscillation of the electrons about the grid of a positive-grid triode. In order for this mechanism to function there must be a sorting of unfavorable electrons by the plate (or by the cathode in the event that the plate is operated quite negative with respect to the cathode). This type of oscillation mechanism is well described in the literature.<sup>2</sup> Barkhausen-Kurz oscillations have been observed to exist without a resonant circuit connected between the tube electrodes. The application of a tuned circuit results in higher interelectrode rf voltages which increase the energy transfer from the electrons to the electric field and intensify the sorting mechanism, making it possible to obtain higher efficiencies.

Barkhausen-Kurz oscillations can be divided into two classes: fundamental-mode, and harmonic-mode. To simplify the discussion, consider parallel-plane electrodes, and let it be assumed that the cathode-grid and grid-plate spacings are equal. For fundamental-mode operation the electrons take a full period to travel from the cathode to the plate and back to the cathode. The rf field can exist in either or both of the interelectrode regions; however, if it exists in both regions, then the two fields must be in phase. Under these conditions it is also possible to obtain odd-harmonic oscillations in

which the transit time of the electrons from the cathode to the plate and back to the cathode is an odd number of periods of the rf voltage. If the rf field exists in only one interelectrode region, or if the two fields are of opposite phase, then it is possible to obtain even-harmonic oscillations.

## VELOCITY VARIATION OSCILLATIONS

As soon as the rf voltage, built up in the interelectrode spaces, reaches a peak value on the order of one-tenth the dc voltage, a second phenomenon becomes appreciable. The electrons obtain large velocity variations which result in bunching and working of the electrons on the field, just as in klystrons and other velocity-variation tubes. Whereas the electron mechanism is quite simple, the mathematics describing it is not. For this reason, one of the simplest cases is analyzed here. Parallel plane geometry is assumed with a resonant circuit connected between grid and plate. This particular location of the tuned circuit was chosen because it is better adapted to high-frequency generators. The effects of space charge are neglected, and it is assumed that the electrons are intercepted by the grid after one transit of the grid-to-plate region. The assumptions of parallel planes and no electrons returning into the cathode-to-grid region can be met fairly well in practice by the application of electron optical principles. It has been observed<sup>3</sup> that a combination of space charge and the proper reflecting field can produce a ring-shaped refocus of the beam. The mathematical consideration of an oscillator in which the electrons are allowed to return into the cathode-to-grid region would be extremely difficult. Moreover, it is believed that such a tube would not be useful as a wide-tuning-range oscillator. Whereas the neglect of space charge would seem to be a very serious limitation on the usefulness of the theory, it must be remembered that the first-order effect is to shift the zero-potential plane in the direction of the grid. The field between the grid and the zero-potential plane is found to remain quite uniform. For small ac signals the debunching effect of space charge is not appreciable.

An approximate mathematical solution to this velocity-variation problem is given in the Appendix. Newtonian dynamics is applied to the electron motion to obtain the velocity and displacement as a function of time. For small ac signals an analytic expression for the conversion efficiency is obtained, based on the net gain or loss of energy of the electrons in traversing the grid-plate region. For the large ac signals a graphical

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† Electrical Engineering Department, The Ohio State University, Columbus, Ohio.

<sup>1</sup> H. Barkhausen and K. Kurz, "Die kurzessten mit vakuumrohren herstellbaren wellen," *Phys. Zeits.*, vol. 21, pp. 1-6; 1920.

<sup>2</sup> R. I. Sarbacher and W. A. Edson, "Hyper and Ultrahigh Frequency Engineering," John Wiley and Sons, pp. 521-549; 1943.

<sup>3</sup> O. Heil and J. J. Ebers, "A new wide-range, high-frequency oscillator." *Proc. I.R.E.*, vol. 38, pp. 645-650; June, 1950.

method is used to obtain the conversion efficiency. In order to obtain a better insight into the processes which compose the electronic mechanism, it is helpful to consider (12) of the Appendix. This equation gives the displacement of the electrons as a function of time and can be written as

$$\frac{\beta_0 \omega}{v_0} x = -(\omega t)^2 + \omega t(\beta_0 - 2K \cos \alpha) - 2K[\sin \alpha - \sin(\omega t + \alpha)] \quad (1)$$

where  $\omega$  is the angular frequency of the rf voltage,  $\beta_0$  is the dc transit angle of the electrons,  $K$  is the ratio of the peak rf to the total dc voltage between grid and plate,  $\alpha$  is the phase angle of the rf field at the time the electron enters the grid-plate region, and  $v_0$  is the initial velocity of the electrons corresponding to the grid voltage. This equation could be plotted directly to obtain a picture of the electron displacement curves for various values of  $\alpha$ . However, the result would not give a clear picture because the curves would be parabolas with a sine wave superimposed. If the term  $2K \sin(\omega t + \alpha)$  is transferred to the left side of the equation, there results

$$\begin{aligned} \frac{\beta_0 \omega}{v_0} x - 2K \sin(\omega t + \alpha) \\ = -(\omega t)^2 + \omega t(\beta_0 - 2K \cos \alpha) - 2K \sin \alpha. \end{aligned} \quad (2)$$

If the change of variable

$$X = \frac{\beta_0 \omega}{v_0} x - 2K \sin(\omega t + \alpha) \quad (3)$$

is made, (2) becomes

$$X = -(\omega t)^2 + \omega t(\beta_0 - 2K \cos \alpha) - 2K \sin \alpha. \quad (4)$$

The form of (4) indicates that in the new  $X$  and  $\omega t$  co-ordinate system the displacement curves become true parabolas.

To plot the curves the  $X$  and  $\omega t$  co-ordinate system is constructed according to (3). A parabolic template determined by the equation

$$X = -(\omega t)^2 + (\omega t)\beta_0$$

can then be constructed. The intersection of the  $X=0$  axis, in the  $X$  and  $\omega t$  co-ordinate system, and the parabola can be determined by a calibration of the parabola as a function of  $\alpha$  according to (4). By this method curves are plotted in Figs. 1, 2, and 3 for  $K=0.4$ ,  $0.8$ , and  $1.0$ , respectively.<sup>4</sup> Electrons are shown entering the grid-plate region at intervals of  $22\frac{1}{2}$  degrees. To simplify the picture, only returning electrons are shown during the last period. The dc transit angle  $\beta_0$  is the same in all

figures and is equal to 7.60 radians. It is shown in the Appendix that this dc transit angle is the optimum angle for first-mode operation.

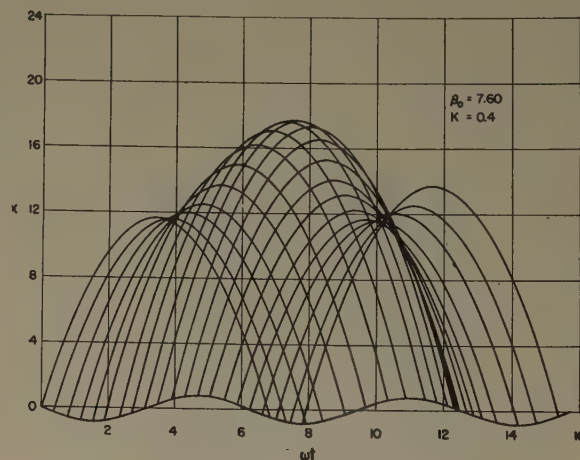


Fig. 1—Velocity modulation, bunching, and working in a retarding-field oscillator.  $K=0.4$ .

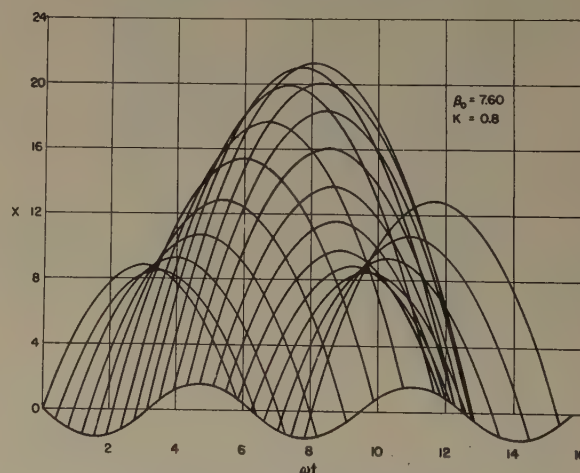


Fig. 2—Velocity modulation, bunching, and working in a retarding-field oscillator.  $K=0.8$ .

It is seen that upon entering the grid-plate region the electrons receive a velocity variation dependent upon the phase angle of the rf grid-to-plate voltage at their time of entry. Since the plate is negative with respect to the cathode, the electrons drift and become bunched in space. Under optimum conditions, the bunch is formed after the electrons have reversed direction, and the bunch returns to the grid at a time when the rf electric field opposes their motion so that the electrons deliver energy to the rf field. In Fig. 1 it is seen that for  $K=0.4$  the bunch is poorly formed; many electrons return to the grid during a time when they continue to take energy from the rf field. In Fig. 2, for  $K=0.8$ , the bunch is well formed. By observing the phase of the sine wave which is used as a co-ordinate, it is seen that the bunch returns at an optimum time for delivering energy to the rf field. In Fig. 3 (see following page), for  $K=1.0$ , the electrons are over-bunched. A theoretical analysis (see Appendix) indicates a maximum efficiency

<sup>4</sup> This method of picturing electron motion was suggested by O. Heil and has been used by H. W. Heil in a German patent application: "Sekundarelektronemission," No. H 168 549 a/21 a4.

for  $K=0.88$ ; thus there seems to be good correlation between bunching and efficiency.

For a reflex klystron in which the rf field is concentrated between two grids and in which the electrons drift and bunch in an rf field-free repeller region, it is found that the optimum drift angles in the repeller region are given by

$$\theta = 2\pi(n + 3/4), n \text{ an integer.} \quad (5)$$

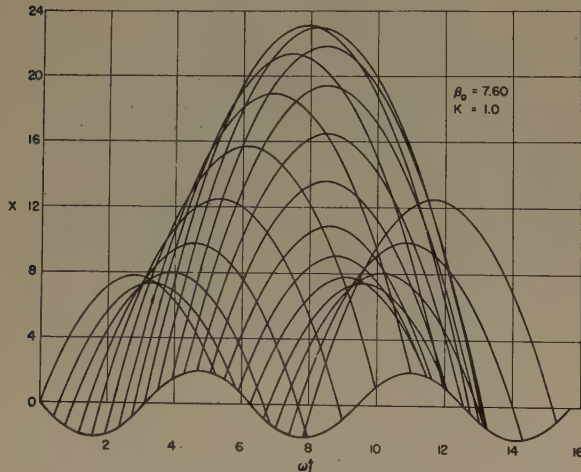


Fig. 3—Velocity modulation, bunching, and working in a retarding-field oscillator.  $K=1.0$ .

In the Appendix it is shown that the optimum drift angle for the first three modes of a parallel-plane retarding-field oscillator are  $2.42\pi$ ,  $4.44\pi$ , and  $6.45\pi$ . Thus the transit angles for optimum efficiency could be written approximately as

$$\beta_0 = 2\pi(n + 5/4). \quad (6)$$

Now if this transit time is divided into three parts as follows: (a)  $\pi/2$  radians for velocity modulation, (b)  $2\pi(n+3/4)$  radians for drifting and bunching, and (c)  $\pi/2$  radians for working, an excellent correlation with reflex klystron behavior is obtained. A careful study of Fig. 2 indicates that the above division of the total transit time is indeed quite accurate. Since the energy transfer between the field and the electron is measured by  $\int \mathbf{E} \cdot d\mathbf{l}$ , most of the energy interchange occurs on the steep sections of the parabola (the modulating and working times) and very little energy interchange occurs at the top of the parabola (the drift or bunching time). In a reflex klystron, bunching occurs around an electron which crosses the gap when the rf field is zero and increasing in such a direction as to decelerate the electron. In the case of a plane retarding-field oscillator, bunching occurs around an electron which passes the grid when the rf field has its maximum accelerating value.

The small-signal theory, as developed in the Appendix, is of no value in determining the amplitude of the oscillations and the efficiency when the oscillator is working into a particular load. However, it provides a good criterion for oscillations to start. By equating the expressions for the power delivered by the beam and the

power dissipated by the load, as derived in the Appendix, the following equations for the starting currents are obtained:

$$I_{0s} = 1.11 \times 10^{-12} \omega^2 d^2 G \text{ for mode 1,} \quad (7)$$

$$I_{0s} = 0.51 \times 10^{-12} \omega^2 d^2 G \text{ for mode 2,} \quad (8)$$

$$I_{0s} = 0.36 \times 10^{-12} \omega^2 d^2 G \text{ for mode 3.} \quad (9)$$

As a typical example, assume

$$f = 6,000 \times 10^6 \text{ cps,}$$

$$d = 10^{-4} \text{ meters,}$$

$$G = 2.5 \times 10^{-5} \text{ mho,}$$

then

$$I_{0s} = 23.6 \text{ ma for mode 1,}$$

$$I_{0s} = 10.9 \text{ ma for mode 2,}$$

$$I_{0s} = 7.7 \text{ ma for mode 3.}$$

Such starting currents are quite easily obtained.

From the description of the tubes and experimental results described in the literature, it is difficult to determine whether the Barkhausen-Kurz mechanism or the velocity-variation mechanism was responsible for the oscillations observed.<sup>5</sup> Because the two mechanisms can occur in the same tube under identical conditions, a tabulation of the optimum transit angles in the grid-plate region for different modes of operation furnishes a criterion for determining which mechanism is responsible for the oscillations, as in Table I. Since some of these transit angles differ by relatively small amounts,

TABLE I

Type of Oscillation	Transit Angle
Barkhausen-Kurz	$\pi$
Barkhausen-Kurz	$2\pi$
Velocity Variation	$2.42\pi$
Barkhausen-Kurz	$3\pi$
Barkhausen-Kurz	$4\pi$
Velocity Variation	$4.44\pi$
Barkhausen-Kurz	$5\pi$

it seems probable that many of the Barkhausen-Kurz oscillations reported in literature were actually of the velocity-variation type, particularly in cases where optimum output was obtained with the plate quite negative with respect to the cathode.

Unfortunately, the sorting mechanism which is essential for Barkhausen-Kurz oscillations also can occur in velocity-variation oscillations. If the electrons which gain energy in crossing from grid to plate (see Fig. 2) are collected by the plate, the efficiency of the velocity-variation mechanism is definitely decreased. This results from the fact that these electrons are capable of delivering energy to the rf field. This would not be true if the dc transit angle were adjusted to  $2\pi$  radians (for

<sup>5</sup> E. C. S. Megaw, "Electronic oscillations," *Jour. IEE*, (London), vol. 72, pp. 313-25; 1933.

Barkhausen-Kurz oscillations) instead of  $2.42\pi$  radians. The entire effect of electrons striking the plate is complicated by secondary electrons. If the electrons strike the plate with more than 20 volts of energy, secondaries will be produced. With large rf voltages, it has been observed that the secondary emission ratio often is much larger than one. The effect of these secondaries on the oscillation mechanism would be difficult to determine analytically.

### EXPERIMENTAL RESULTS

In a recent paper<sup>6</sup> a new tube is described which is essentially a retarding-field oscillator adapted to a resonant cavity. To see how this tube evolves from a reflex klystron, consider Fig. 4. At the top is shown a reflex

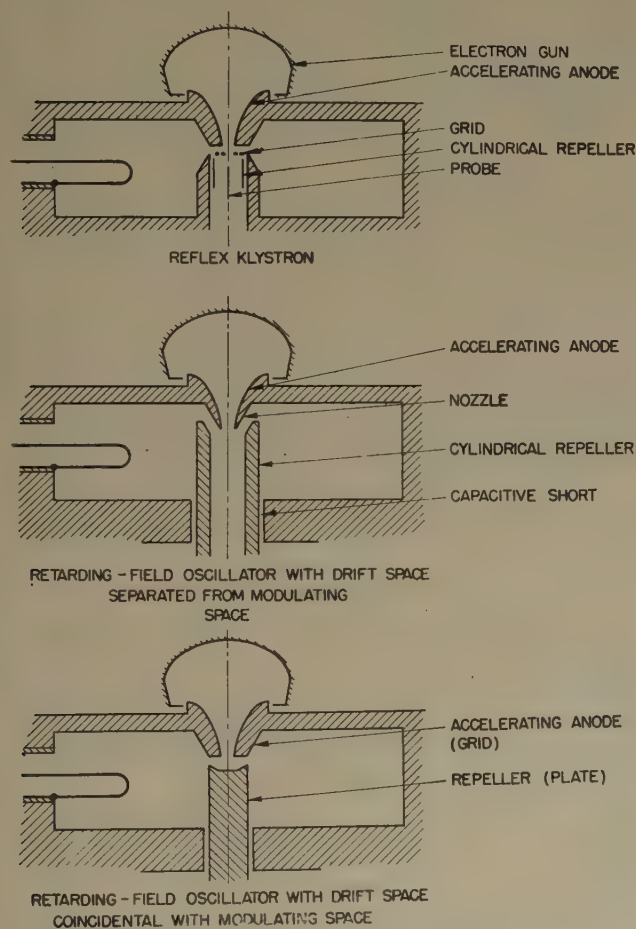


Fig. 4—Retarding-field oscillators.

klystron which is capable of generating high-frequency power with an efficiency of approximately 1.5 per cent. The electrons are velocity modulated in the concentrated rf field between the anode and grid; they then drift and bunch in the repeller region and return to do work in the rf field. In the center is shown a tube such as described by Heil and Ebers. The electrons are velocity modulated by the concentrated rf field near

the nozzle. They then drift and bunch in a relatively weak rf field, and return to do work on the strong rf field.

Calculations of electron transit times for the oscillator shown in the center of Fig. 4 for the highest frequency oscillations show that the electrons only enter the repelling field a distance comparable to half the diameter of the anode aperture. In this region the ac and dc fields are quite uniform. Moreover, the transit time corresponds to approximately 1.1 periods, as compared to  $\frac{3}{4}$  period for optimum efficiency of a reflex klystron. For these reasons it was decided to undertake the mathematical development given in the Appendix and to build a tube such as shown at the bottom of Fig. 4. In this case the fields are concentrated and quite uniform between the grid and repeller. The potential distribution for this electrode configuration is plotted in Fig. 5. Actually, the chronological order of the development of these tubes is correct, but it could be argued that the reverse order would have been more logical.

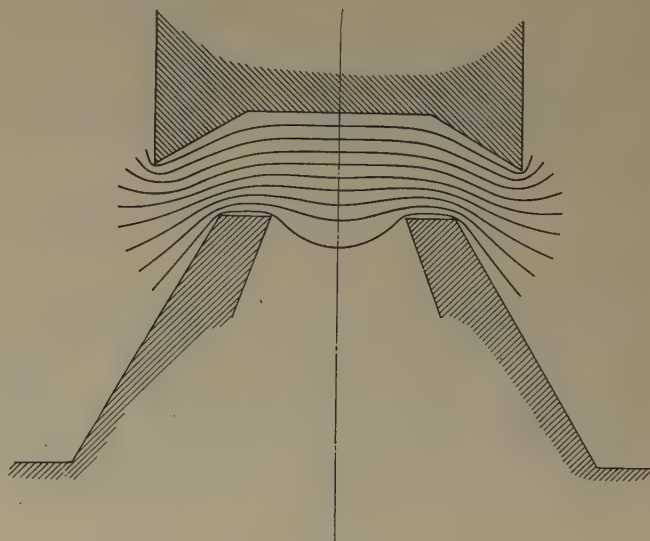


Fig. 5—Potential distribution in a planar, retarding-field oscillator.

A drawing of a tube designed to have a uniform repeller field is shown in Fig. 6. In order to obtain a check on the theory of retarding-field velocity-variation oscillations presented here, a design was chosen which would fit the assumptions of the theory as closely as possible. The field between the grid (hereafter called the anode) and negative plate (hereafter called the repeller) is quite uniform, as shown in Fig. 5. Very few electrons make more than one transit of the interaction gap, since the beam spreads on entering the cavity, and upon its return strikes the flat portion of the anode.

The actual tube was built on a demountable pump station. The accelerating anode was made in two parts so that the beam current could be varied with the cavity voltage held constant. The gun used in this model was developed by O. Heil and has a perveance of  $4.33 \times 10^{-6}$ .

<sup>6</sup> O. Heil and J. J. Ebers, *ibid.*

The power output was obtained by inserting a coupling loop into the cavity through a quartz tubing. A choke was provided to prevent loss of high-frequency energy on the repeller lead. The distance  $x$  of Fig. 6 was varied in different models.

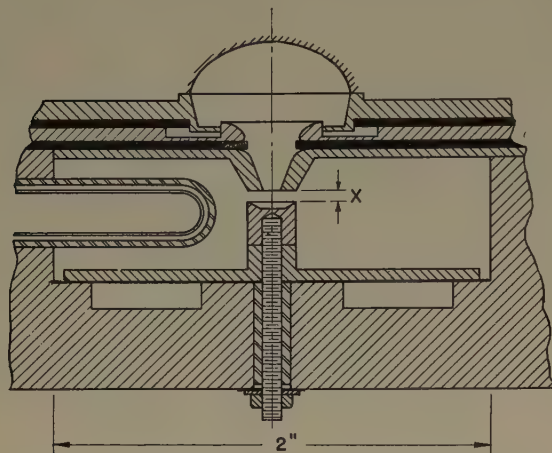


Fig. 6—Drawing of a planar, retarding-field oscillator.

Calculation of the transit angle of the electrons in the interaction gap may be made from (14), which may be written as

$$\beta_0 = 1.27 \times 10^4 \frac{d\sqrt{V_{A2}}}{\lambda(V_{A2} + V_R)}, \quad (14(a))$$

where  $V_{A2}$  is the second anode or cavity potential, and  $V_R$  is the magnitude of the negative repeller potential. Since the field extends into the anode aperture (see Fig. 5) the value of  $d$  is not exactly equal to the dimension  $x$  shown in Fig. 6. As a correction, the distance from the flat anode surface to the 0.9 equipotential surface was added to  $d$  in all cases (about 0.012 inch). A tabulation of  $\beta_0$  for various values of  $x$ , and the corresponding measured resonant wavelength of the cavity are given in Table II. The theoretical optimum transit angles for modes 1 and 2 are 7.60 and 13.8 radians, respectively;

TABLE II

$x$	$\lambda$	$\beta_0$	
		Mode #1	Mode #2
0.0395"	10.4 cm	8.75 rad.	
0.063"	9.15 cm	8.55 rad.	15.0 rad.
0.083"	8.55 cm	8.90 rad.	14.9 rad.
0.073"	8.75 cm	8.25 rad.	15.2 rad.
0.070" (grids)	8.90 cm	7.80 rad.	

however, it is recalled that space charge pushes the zero potential plane toward the grid. Thus it would be expected that transit angles, as calculated above, could be larger than the theoretical values. It has been observed that as the beam current is decreased, the calculated angles approach the theoretical values.

A curve of power output and efficiency as a function of anode voltage is shown in Fig. 7. Since the efficiency increases at a constant rate, it is probably true that

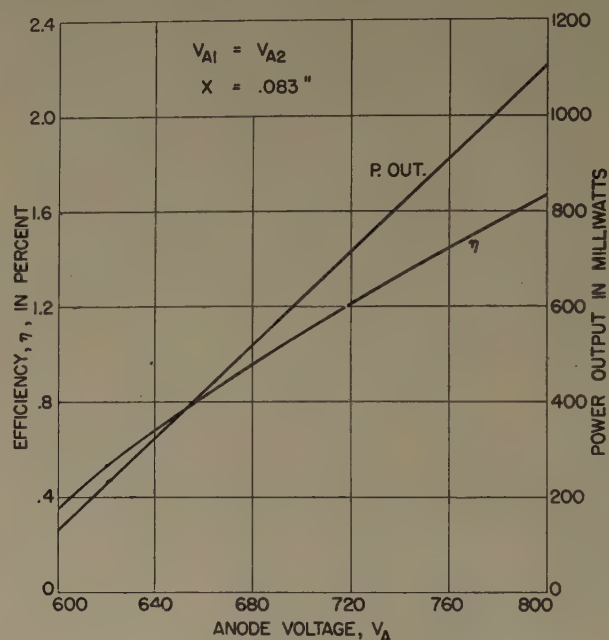


Fig. 7—Variation of power output and efficiency with anode voltage.

space-charge debunching is not a limiting factor in efficiency. A curve of power output and efficiency as a function of beam current is shown in Fig. 8.

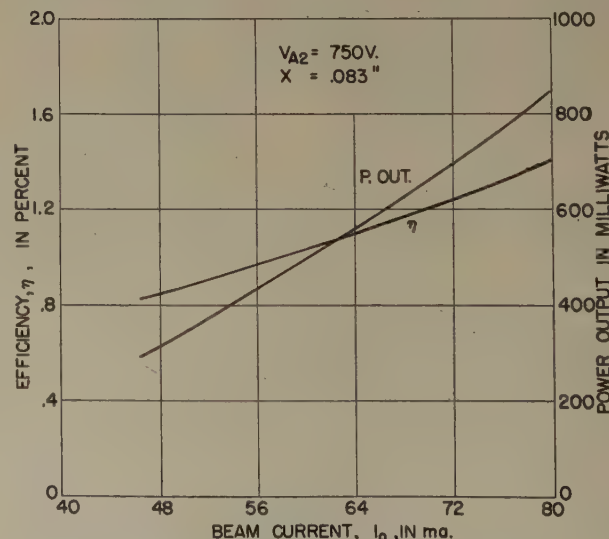


Fig. 8—Variation of power output and efficiency with beam current.

From additional data obtained on this tube, it was found that approximately twice as much energy was dissipated in the cavity as in the load. The largest portion of these losses occur in the repeller by-pass circuit. Recently, an improved-design tube was operated at

6,000 mc with an over-all efficiency of 4.5 per cent and a conversion efficiency of approximately 6.0 per cent.<sup>7</sup>

### CONCLUSIONS

Of the two fundamentally different methods of generation of high-frequency energy by the use of a positive-grid or retarding-field oscillator, the velocity-variation type is the more adaptable to wide-range, centimeter-wave oscillations. The difference between the power produced in such oscillators and the theoretical values offers promise of greater efficiencies. The upper limit on the efficiency obtainable in practice is not known, but factors such as space-charge debunching and nonuniform transit times will probably make the theoretical value unobtainable. Work can be done toward determining the best electron optics and the best cavities for such an oscillator. To counteract the effects of space charge, it is possibly true that higher voltages and lower currents should be used. This would also have the advantage of increasing the cavity gap length and hence the cavity shunt impedance.

The principal advantage of these oscillators over reflex klystrons lies in their simplicity. From data which has been obtained to date, the electronic tuning range seems to be comparable to reflex klystrons; about one per cent. The cone-shaped anode (Fig. 4) probably lends itself better to wide-range tuning than one with a plane anode and repeller, since it concentrates the fields in the vicinity of the anode and allows the electrons room in which to drift without striking the repeller. If only a limited tuning range is desired, it is possible that a plane electrode system would give best results.

### ACKNOWLEDGMENTS

The author thanks his associates in the electron tube laboratory who have made suggestions concerning the theory, and who have aided in the construction of the tubes discussed in this paper. The author wishes to express his appreciation to E. M. Boone for his valuable criticism and suggestions in the capacity of advisor for doctoral research.

### APPENDIX

#### *Mathematical Analysis of Velocity-Variation Effects in the Grid-Plate Region of a Retarding-Field Oscillators<sup>8</sup>*

Consider the parallel-plane electrode arrangement and electrical connections shown in Fig. 9. Electrons leave the cathode and are accelerated to a velocity  $v_0$  corresponding to the grid voltage  $V_0$ . The plate is op-

erated at a potential which is negative with respect to the cathode; thus the electrons are reflected in the grid-plate region. Upon their return to the grid it will be assumed that the electrons are collected. For simplicity it will be assumed that the electrodes are infinite, parallel planes. The effects of space charge will be neglected. The object of this analysis is to obtain an expression for the transfer of energy between the electron stream and the rf field in the grid-plate region.

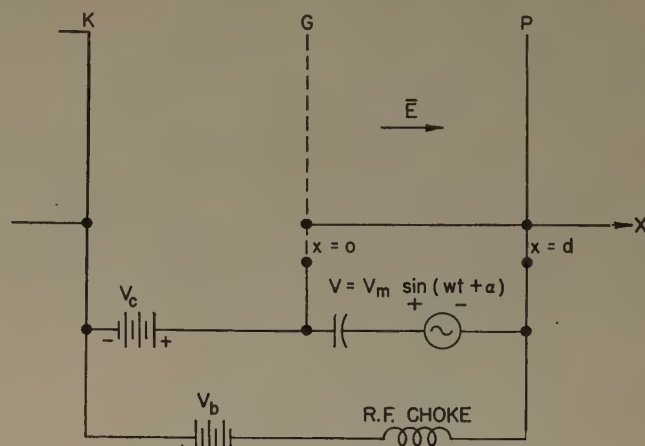


Fig. 9—Circuit for analyzing velocity-variation oscillations.

If the magnitude of the dc grid-to-plate voltage is defined as

$$V_1 = V_b + V_c, \quad (10)$$

and if the force on an electron is equated to the rate of change of momentum, an expression is obtained which can be integrated to give the velocity and displacement of an electron, which enters the grid-plate region when the phase angle of the rf field is  $\alpha$ , as a function of time. The velocity is

$$v = v_0 - \frac{e}{md\omega} [V_1\omega t - V_m\{\cos(\omega t + \alpha) - \cos \alpha\}] \quad (11)$$

and the displacement measured from the grid plane is

$$x = v_0 t - \frac{e}{md\omega^2} \left[ \frac{V_1(\omega t)^2}{2} - V_m\{\sin(\omega t + \alpha) - \omega t \cos \alpha - \sin \alpha\} \right]. \quad (12)$$

If  $\tau$  is the total electron time of transit of the grid-plate region, then the transit angle will be given by

$$\beta = \omega\tau. \quad (13)$$

The transit angle in the absence of an rf field is defined as  $\beta_0$ ;

$$\beta_0 = \frac{2mdv_0\omega}{eV_1}. \quad (14)$$

If the further definition is made that

<sup>7</sup> These results will be described in a forthcoming article by J. Moll and R. Wilmarth of the Ohio State University Tube Laboratory.

<sup>8</sup> An analysis of this problem has been done by W. Kleinstaub, "Die bremsfeldanfachung bei grossen wechselfspannungen," *Hochfreq. und Elektroak.*, vol. 57, pp. 1-10; 1941, by a different method with similar results. The processes of velocity modulation, bunching, and working were not apparent nor was the reason why the different modes exist.

$$K = \frac{V_m}{V_1}, \quad (15)$$

then (11) and (12) become the following dimensionless equations:

$$\frac{v_r}{v_0} = 1 - \frac{2}{\beta_0} [\beta + K \{ \cos \alpha - \cos (\alpha + \beta) \}] \quad (16)$$

$$0 = -\beta^2 + \beta(\beta_0 - 2K \cos \alpha) - 2K[\sin \alpha - \sin (\alpha + \beta)], \quad (17)$$

for electrons at  $x=0$ .

#### Small-Signal Theory

Equation (17) is a transcendental equation in  $\beta$ , and if an analytical solution is to be obtained, the terms  $\sin \beta$  and  $\cos \beta$  must be expanded in power series. However  $\beta$  is large, in general, and an expansion about  $\beta_0$  is used. If this is done and terms of the zero, first, and second order only are retained, a solution is obtained which, when substituted into (16), gives

$$\begin{aligned} \frac{v_r}{v_0} = - \left[ 1 + \frac{2K}{\beta_0^2} \{ 2 \sin (\alpha + \beta_0) - 2 \sin \alpha \right. \\ \left. - \beta_0 \cos (\alpha + \beta_0) - \beta_0 \cos \alpha \} \right. \\ \left. + \frac{2K^2}{\beta_0^2} \{ 1 + \cos^2 \alpha - 2 \cos \beta_0 \right. \\ \left. - 2\beta_0 \cos \alpha \sin (\alpha + \beta_0) + \sin^2 (\alpha + \beta_0) \} \right]. \quad (18) \end{aligned}$$

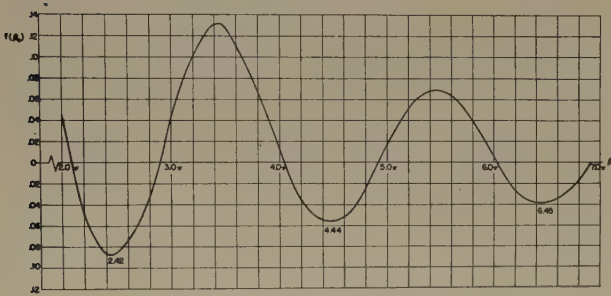


Fig. 10—Variation of  $f(\beta_0)$  with  $\beta_0$ .

The conversion efficiency of the mechanism (transfer of electron beam energy to rf field energy) is given by the simple equation,

$$\eta_{\text{conv}} = 1 - \frac{1}{2\pi} \int_0^{2\pi} \frac{v_r^2}{v_0^2} d\alpha. \quad (19)$$

Because of the integral properties of sinusoidal functions, the square of (18) is easily integrated. The resulting efficiency is given by

$$\eta_{\text{conv}} = -4K^2 \left[ \frac{4 + 3\beta_0^2 - (4 + \beta_0^2)(\cos \beta_0 + \beta_0 \sin \beta_0)}{\beta_0^4} \right] \quad (20)$$

which can be written as

$$\eta_{\text{conv}} = -4K^2 f(\beta_0). \quad (21)$$

The function  $f(\beta_0)$  is plotted in Fig. 10. The negative values of this function are of interest since they correspond to positive values of efficiency as given by (21), and hence they represent a net transfer of energy from the electron stream to the rf field. It is observed that negative maxima occur for  $\beta_0$  equal to 7.60, 13.80, and 20.22 radians. These regions will hereafter be referred to as modes 1, 2, and 3, respectively.

If the dc voltages have been adjusted to give the optimum drift angles mentioned in the foregoing paragraph, the efficiency can be plotted as a function of  $K$ , the ratio of ac and dc voltage, for the three modes. These are the parabolic curves in Fig. 11. Now let it

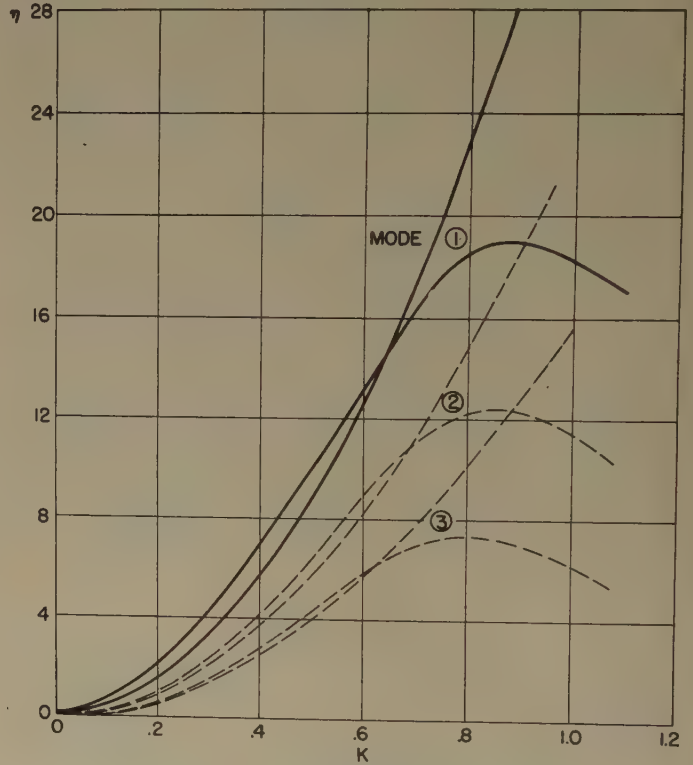


Fig. 11—Small-signal and large-signal efficiency as a function of  $K$

be assumed that the mechanism described above is operating as an oscillator. A parallel resonant circuit with shunt conductance  $G$  is connected between grid and plate. A shunt conductance  $G$  is assumed to dissipate all the conversion energy. If the circuit is oscillating it must be true that the power delivered by the beam is equal to the power dissipated in the conductance  $G$ . Thus if  $P_{\text{del}}$  is the power delivered and  $P_{\text{dis}}$  is the power dissipated, then

$$P_{\text{del}} = P_{\text{input}} \eta_{\text{conv}} = I_0 V_c \eta_{\text{conv}} = -4I_0 V_c K^2 f(\beta_0)$$

or

$$P_{\text{del}} = \frac{4I_0 V_c f(\beta_0)}{V_1^2} V_m^2 \quad (22)$$

and

$$P_{dis} = \frac{1}{2}GV_m^2. \quad (23)$$

The power-delivered and the power-dissipated curves are both proportional to the square of the rf voltage, and hence will not intersect. This implies that oscillations would build up in intensity indefinitely provided they would start. Thus it is obvious that the efficiency curves obtained are inconsistent with experiment and whereas they may be quite accurate for small signal, they, by necessity, must exhibit a saturation effect for the condition of large ac signals.

### Large-Signal Theory

In order to obtain the saturation effect mentioned above, it is necessary to obtain more accurate solutions of (17). A sufficiently accurate analytical solution could be obtained, but a solution by means of a series of approximations is probably easier and permits an accuracy only dependent on the care in making the computations.

Equation (17) can be written as

$$\beta = (\beta_0 - 2K \cos \alpha) - 2K \left[ \frac{\sin \alpha - \sin (\alpha + \beta)}{\beta} \right]. \quad (24)$$

As a first approximation,  $\beta$  can be taken equal to  $(\beta_0 - 2K \cos \alpha)$  and this value of  $\beta$  substituted in the right-hand side of (24). This gives a new value of  $\beta$  which can again be substituted in (24). If this procedure is repeated two or three times, a sufficiently accurate value of  $\beta$  will be obtained. A plot of the variation of  $\beta$  with  $K$  for different values of  $\alpha$  is shown in Fig. 12. The dc transit angle is taken to be 7.60 radians which corresponds to the optimum angle for first-mode operation as determined by the small-signal theory. The

dotted lines indicate the first approximation. The values of  $\beta$  obtained can then be substituted in (16). The ratio  $v_r^2/v_0^2$  can be plotted as a function of  $\alpha$  and the efficiency obtained by graphical integration. These results are also shown in Fig. 11, where efficiency is plotted as a function of  $K$ . Also plotted is a possible (not calculated) variation of efficiency for the other modes.

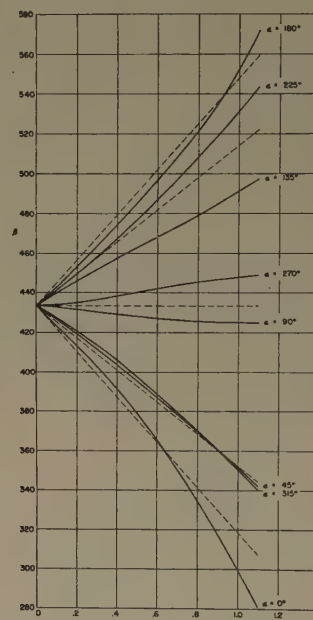


Fig. 12—Variation of transit angle with  $K$  for various  $\alpha$ .

The question naturally arises as to whether the value of  $\beta_0$  chosen for the first mode actually gives optimum efficiency for large signals. The efficiency was calculated for values of  $\beta_0$  on either of 7.60 radians, and in both cases a decrease was obtained.

### CORRECTION

David Atlas, co-author with Ludwig Katz of the correspondence, "Optimum Vertical Resolution in Microwave Probing of the Atmosphere," which appeared on page 1341 of the October issue of the PROCEEDINGS OF THE I.R.E., has brought the following error to the attention of the editors:

Equations (1) and (2) should read as follows:

$$t = p \sin \theta + h\phi/\tan \theta. \quad (1)$$

and

$$\cos^2 \theta - \cos \theta + \frac{\phi h}{p} = 0. \quad (2)$$

# Improvements in Image Iconoscopes by Pulsed Biasing the Storage Surface\*

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**Summary**—In storage-type television camera tubes using high-velocity electrons for scanning, such as the iconoscope and image iconoscope, the storage surface is stabilized to an equilibrium potential by secondary emission. A number of undesirable characteristics, such as spurious signals, absence of "black-level" information, and relatively low efficiency, are usually associated with tubes of this kind. However, these disadvantages are considerably reduced if the mean potential of the storage surface is shifted negatively. A method is investigated for obtaining such required potential shift by periodically irradiating the storage surface with high-velocity electrons while simultaneously reducing the collector potential, these periodic processes being carried out during suitable intervals in picture transmission, such as the frame-blanking period.

Application of this principle has been most successful in cases where the picture is projected intermittently as in the "memory-scanning" method of film transmission, but for continuous pickup the advantages are only partly attainable.

## INTRODUCTION

FOR STABLE OPERATION of storage-type camera tubes, the potential of the storage surface must be restored to an equilibrium value at each scanning. There are two stable potentials which the insulated storage-plate surface can assume under bombardment, depending on whether secondary electrons are emitted in excess of unity ratio or not. If the electrons are of relatively high velocity, e.g., of the order of 1,000 volts, the surface, because of secondary emission, assumes a potential close to that of the collecting electrode which is usually common with the tube anode. But if the electron velocity at the storage plate is close to zero, there are substantially no secondary electrons, and the surface accumulates charge until its potential approximately equals that of the cathode of the electron source.

In camera tubes of the iconoscope and image-iconoscope type<sup>1,2</sup> the surface-potential stabilization is obtained by the first method, that is, by secondary emission. This "anode-potential stabilization" has the great advantage of being completely stable at all light levels, but tubes operated in this manner show undesirable effects because of "secondary electron redistribution." In such tubes the storage surface is insulated, and an equilibrium must be maintained between the number of electrons arriving at and leaving this surface. This in

turn requires that, on the average, all of the emitted secondary electrons in excess of one for each arriving primary electron must return to the surface, thus giving rise to "redistribution" effects. These effects become apparent as spurious signals and cause other defects in the pictures.

The second method, known as "cathode-potential stabilization," is employed, with considerable success, in the Orthicon and image-Orthicon camera tubes used in modern television.<sup>3-6</sup> The scanning beam does not liberate free electrons for redistribution, and hence there are no spurious signals from this source. Also, higher storage efficiency may be obtained, as well as preservation in some tubes of true black level in the signal. On the other hand, low-velocity scanned tubes are not without limitations.<sup>7</sup>

Consideration of the signal generation processes show that some of the major advantages of low-velocity scanning can be obtained in high-velocity scanned tubes by shifting the mean potential of the storage surface in a negative direction. There have been a number of proposals for obtaining this desired effect: by use of semiconducting storage plates,<sup>8</sup> by continuous or pulsed diffuse irradiation of the storage surface with low-velocity electrons,<sup>9</sup> by scanning with very high-velocity electrons,<sup>10,11</sup> and so on. However, apart from the use of bias-light and rim-light techniques in iconoscopes for film transmission<sup>12-14</sup> which obtain the required results

\* A. Rose and H. Iams, "The Orthicon, a television pickup tube," *RCA Rev.*, No. 4, pp. 186-199; October, 1939. "Television pickup tubes using low-velocity electron-beam scanning," *Proc. I.R.E.*, vol. 27, pp. 547-555; September, 1939.

† A. Rose, P. K. Weimer, and H. B. Law, "The image Orthicon, a sensitive television pickup tube," *Proc. I.R.E.*, vol. 34, pp. 424-432; July, 1946.

‡ J. D. McGee, "A review of some television pickup tubes," *Jour. IEE* (London), vol. 97, pt. III, pp. 377-392; November, 1950. "Distant electric vision," *Proc. I.R.E.*, vol. 38, pp. 596-608; June, 1950.

§ R. B. Janes, R. E. Johnson, and R. S. Moore, "Development and performance of television-camera tubes," *RCA Rev.*, vol. 10, no. 2, pp. 191-223; June, 1950.

|| L. H. Bedford, "Television-camera tubes," *Wireless Eng.*, vol. 28, pp. 4-16; January, 1951.

¶ H. Salow, "Speichernde Bildfänger mit halbleitendem Dielektrikum," *Fernsehen und Tonfilm*, pp. 1-4; January, 1939.

§ A. W. Vance and H. Branson, U. S. Patent 2,147,760, issued February 21, 1939. (British Patent 434,942.)

|| V. K. Zworykin and G. A. Morton, "Television," John Wiley and Sons, Inc., New York, N. Y., p. 306; 1940.

¶ J. D. McGee and H. G. Lubszynski, "E. M. I.—cathode-ray television transmission tubes," *Jour. IEE* (London), vol. 84, p. 131; 1939.

|| W. S. Percival, C. O. Browne, L. R. J. Johnson, and F. Blythen, British Patent 490,845, accepted August 22, 1938.

¶ O. H. Schade, U. S. Patent 2,368,884, issued February 6, 1945. (British Patent 569,436.)

|| S. Helt, "Practical Television Engineering," Murray Hill Books, Inc., New York, N. Y., pp. 188-190; 1950.

\* Decimal classification: R583.6. Original manuscript received by the Institute, September 4, 1950; revised manuscript received July 11, 1951.

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‡ Cathodeon Ltd., Cambridge, England.

§ V. K. Zworykin and G. A. Morton, "Television," John Wiley and Sons, Inc., New York, N. Y., Chaps. 10 and 11; 1940.

|| J. D. McGee, "Electronics," The Pilot Press, London, England, Edited by B. Lovell, Chapt. 4; 1947.

to a partial degree, it is not known to the authors that any of the proposed methods have been successfully used in a practical television service.

The paper deals with investigations into a method of obtaining the required shift of the equilibrium potential of the storage surface by periodically charging the storage capacitance during the frame-blanking intervals,<sup>15</sup> a system which has made possible considerable improvements in film transmission using storage-type camera tubes.<sup>16</sup>

#### OPERATION OF IMAGE ICONOSCOPE-TYPE TUBES UNDER NORMAL CONDITIONS

The investigations described have been carried out with tubes known commercially as the "Photicon,"<sup>17</sup> which is of the image-iconoscope type, but the proposals are applicable to some other camera tubes employing the storage principle.

Fig. 1 shows a schematic diagram of a tube of this type. As the principle of operation is well known, it will not be discussed in detail. However, it is necessary to draw attention to some of the peculiarities of operation in order to simplify the understanding of the material which follows.

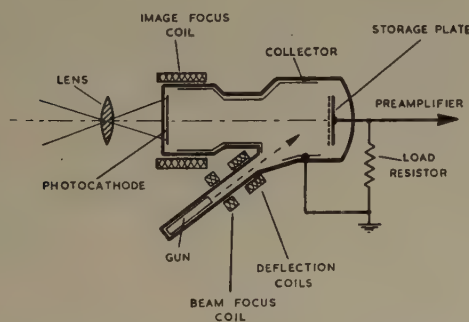


Fig. 1—Schematic diagram of an image iconoscope-type tube.

Up to the stage involving the storage surface, the translation of the picture signal is satisfactory and is at maximum efficiency as the photo current is always saturated. However, at the storage plate, where the picture charge pattern is formed, the signal translation is less satisfactory owing to the unfavorable potential conditions at the scanned surface, which are inherent in the method of surface-potential stabilization by secondary emission.

This will be explained in greater detail in conjunction

<sup>15</sup> Subsequent to the writing of this paper, the authors became aware of the patents: A. V. Bedford, R. D. Kell, U. S. Patent 2,108,097 issued February 15th, 1938, and T. L. Delvaux (Compagnie Francaise Thomson Houston), French Patent 901,393, issued July 25th, 1945, in which the application of such periodic pulsed charging is mentioned for the operation of normal iconoscopes, but obviously these proposals have not been developed to any known practical technique.

<sup>16</sup> W. R. Cheetham, N. Q. Lawrence, and R. Theile, "The design of 16-mm television film-chain employing pulsed Photicon pickup technique," *Jour. Soc. Mot. Pic. & Telev. Eng.*; to be published.

<sup>17</sup> Trade mark of Cathodeon Ltd., Cambridge, England. Registered in the United States and Great Britain.

with Fig. 2, which shows qualitatively the effects of secondary emission at an electron-bombarded target. Fig. 2(a) is a schematic diagram of the experimental setup used in obtaining the information displayed in Fig. 2(b). This setup consists of a vacuum tube having means of generating an electron beam which is accelerated towards a conductive target plate, with external means of varying the potential between the target plate and the collector electrode.

Fig. 2(b) shows the target current  $i_p$  (difference between primary and secondary currents) as a function of the target/collector potential difference  $e$ . This characteristic is mainly determined by the initial velocity distribution of the emitted secondary electrons. The number of secondary electrons collected decreases as the retarding field is increased until eventually all the secondaries are returned and the target current then equals the incident primary current. On the other hand, if the target potential is sufficiently negative to that of

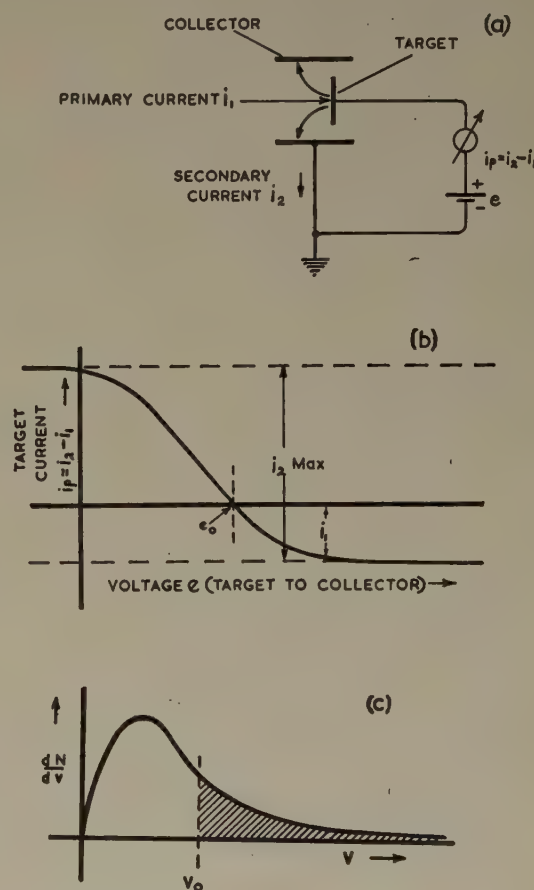


Fig. 2—Qualitative effects of secondary emission: a. Test setup. b. Signal-plate current characteristic. c. Velocity distribution.

the collector, all the emitted secondary electrons are collected and the target current is equal to the excess of secondary current over primary current. Even if no potential difference exists between the target and the collector, the emission velocities are such that complete

collection of the secondary electrons can take place, provided that no appreciable modification of the space potential is caused by the electron charge itself, a condition which is closely approached during normal camera-tube operation. The range between no collection and full collection of the secondary electrons is determined by the distribution of the emission velocities, which usually have a greatest probability value of about 2 volts, the exact value depending on the properties of the bombarded surface, and so forth.

Of particular importance in the operation of camera tubes is the point  $e_0$  in Fig. 2(b). Here the average number of secondary electrons collected equals that of the arriving primary electrons, that is  $i_p = 0$ . At this point it is possible to disconnect the target lead without causing any change in the operating conditions. Alternatively, if by reason of the operating conditions the target current is essentially zero, for example, when the target consists of an insulated layer, then  $e_0$  will automatically be established as the operating equilibrium value. The potential  $e_0$  is determined by the velocity distribution shown in Fig. 2(c). In this curve, the number of electrons  $dN$  per velocity interval  $dv$ , (between  $v$  and  $v+dv$ ) is plotted against  $v$ . The existence of the equilibrium potential  $e_0$  means that only electrons having velocities greater than  $v_0$  can surmount the retarding field,  $v_0$  being defined as that value at which all emitted electrons with velocities from  $v_0$  to infinity have an integrated number equal to that of the incident primary electrons.

Applying these results to image-iconoscope camera tubes in which a concentrated electron beam periodically scans an insulated storage surface, we find that the area immediately under the scanning beam assumes the positive equilibrium potential, and simultaneously the excess secondary electrons are redistributed over neighboring parts of the surface. This low-velocity electron redistribution forms a negative charge layer, which is essential and necessary for the picture charge-pattern development. There is a continuously proceeding interchange of electrons in such manner between the area being scanned, other areas of the storage plate and, of course, the collecting electrode, that the mean storage-plate current is zero over a complete cycle of the scanning process, provided the picture content is constant. The departures of this current from the mean value in positive and negative direction represent the signal modulation. Since, therefore, the black signal is not constant in relation to the interline (zero beam) level which is available as a reference during line-blanking time, it is not possible to use this reference for black-level restoration.

This is one of the serious defects of high-velocity scanned camera tubes, which makes it necessary for the dc level of the outgoing signal to be continually adjusted manually. It is extremely difficult, if not impossible, to carry out this procedure satisfactorily when frequent and violent changes of light level occur,

as often happens in the transmission of cinematograph films.

Other major defects of high-velocity electron-scanned tubes are spurious signals and edge flare, which are due to nonuniformity of the redistribution process. It follows from the description of the surface-potential stabilization by secondary emission, that the area immediately behind the scanning beam is left as the most positive part of the storage surface. Consequently, there is a tendency for the free secondary electrons to migrate in the direction opposite that of the motion of the scanning beam, thus accumulating most negative charge at the areas where the scanning process starts, and least charge at those parts which are scanned at the end of each cycle. As a result of this nonuniform charge distribution, spurious signals are generated in the scanning process, and the modulation ratio due to the picture content is not constant over the picture area. These spurious signals ("tilt and bend" or "dark spot") appear in the transmitted picture as shading of the background level, the shading being most intense at the top left corner of the received picture and decreasing towards the bottom and right-hand edges. This shading can be compensated, but the compensation requires adjustment with changes in picture content.

Edge flare is also caused by the sense of the redistribution, and appears along the edges of the picture where the scanning process ends, particularly at the bottom edge in a conventional television system. As the scanning beam switches immediately to the top after having scanned the bottom part, there is no region of scan-induced secondary electrons following this area in close proximity. As a result of this, the last lines at the bottom of the picture receive very little charge by redistribution. Consequently, the surface potential of this area is less negative than that of the greater part of the storage surface. This results in the signal from this area appearing to be relatively white and having a reduced depth of modulation. The effect is most marked when the lowest part of the picture contains areas of black picture content which meet the bottom edge. But, if the picture area adjacent to this bottom edge is largely white, then there is redistribution of secondary electrons induced by the photoelectrons bombarding the neighborhood, and the effect is much reduced under these conditions.

Another unfavorable consequence of surface-potential stabilization by secondary emission is that the range of possible voltage change at the surface is limited between the positive equilibrium potential and the maximum negative potential due to accumulated redistribution electrons. This leads to low efficiency of storage and to a nonlinear transfer characteristic which has decreasing slope with increasing light levels. Consequently, the maximum possible signal to noise ratio is limited, but these properties of nonlinear transfer characteristic and incomplete storage efficiency are in some respects advantageous. They result in good half-tone

rendition, "sharpness" of definition is retained in pictures including fast-moving subjects, and external gamma correction unit is not required.

#### PRINCIPLE OF IMPROVEMENT BY PULSED BIASING

It is clear from the above considerations that improvements in the characteristics of high-velocity scanned tubes could be expected from the reduction or elimination of secondary electron redistribution. This means that collection of the secondary electrons must be improved, which necessitates a relative shift of the storage-surface potential in a negative direction (see Fig. 2, page 147.)

It is known that temporarily improved pictures may be obtained from an iconoscope or image iconoscope by suddenly increasing the collector potential in a positive direction. Within a short time, however, the storage surface loses its charge because of the increased collection of secondary electrons, the surface potential follows the changed (more positive) collector potential, and new equilibrium conditions are established, which result in the operating conditions reverting to those which existed before the application of the positive potential. In order to maintain the required potential difference between the storage surface and the collector, it is obviously necessary to replace, continuously or periodically, the excess of collected secondary electrons at the emitting surface.

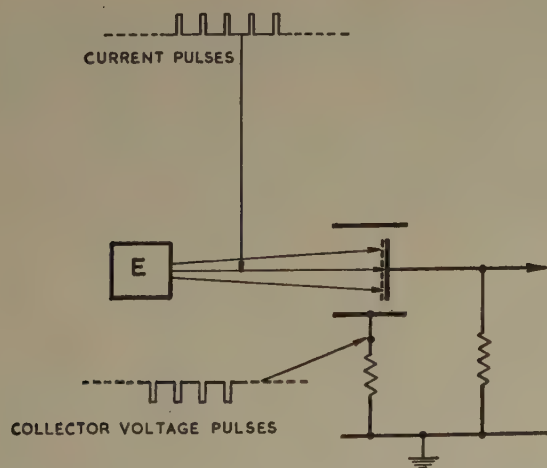


Fig. 3—Basic principle of "pulsed biasing" the storage surface.

This electron replacement may be achieved by a combination of electron pulses sent on to the storage plate and voltage pulses on the collector, as schematically illustrated in Fig. 3. *E* represents a pulsed electron source generating a diffuse beam with velocities of similar order to those of the electrons from the photocathode or the scanning beam. Simultaneously, negative voltage pulses are applied to the collector, thus establishing a retarding field in front of the storage plate. Consequently, during the pulse period, all sec-

ondaries from the storage surface must return to the surface, which becomes progressively more negatively charged, until either equilibrium with the collector pulse potential is established, or, should the amplitude of this potential be very high, until the cessation of the pulse. During the intervals between pulses, the collector reverts to its normal potential, leaving the storage plate charged negatively to it. As a result of this, the tube operates under improved conditions, and, because the charging process is periodically repeated, the improved conditions are maintained.

An estimate of the requirements for the pulsed electron-beam current *i* and the collector amplitude can easily be made. It is assumed that the duration of the blanking interval is 5 per cent of the whole frame period, that the pulsing period *t* occupies approximately half of this interval, and that the total storage-plate capacity *C* is 5,000 pf, these being typical values found in practice. We further assume that the electron source is of high internal impedance, and that the collector pulse amplitude is sufficient to retard substantially all emitted secondary electrons. The process is then time proportionate.

$$\text{Potential change } \Delta e = \frac{\text{additional stored charge}}{\text{capacity}} = \frac{i \times t}{C},$$

therefore,  $i = C \times \Delta e / t$ .

As the required potential shift  $\Delta e$  is of the order of only a few volts (see Fig. 2), the charging pulse current required is of the order of  $10^{-6}$  amps.

Tubes of the image iconoscope type are most suited to the pulsed-bias mode of operation since it is possible to utilize the picture photocathode as the source of electrons *E* noted in Fig. 3. It is necessary only to illuminate the photocathode periodically from a suitably controlled light source, such as a miniature cathode-ray tube as shown in Fig. 4 (see following page), a gas-discharge tube, or an incandescent lamp in conjunction with a rotating or vibrating shutter.

Fig. 4 illustrates the procedure adopted for the transmission of cinematograph films, utilizing intermittent projection on to the photocathode of the pickup tube during the frame-blanking period (memory scanning). The mode of operation is as follows: The whole frame period is divided into three intervals. During the first interval the charging of the storage surface takes place according to the method described. During the following period the image of the stationary film is projected on to the tube photocathode, whereby a charge pattern corresponding to the picture content is developed on the surface of the storage plate under improved conditions. The total time of these two intervals must not exceed the duration of the frame-blanking interval. During the third period of the cycle the charge pattern is evaluated by the scanning beam under conditions of high efficiency as almost all the secondary electrons generated are collected. Picture projection and scanning

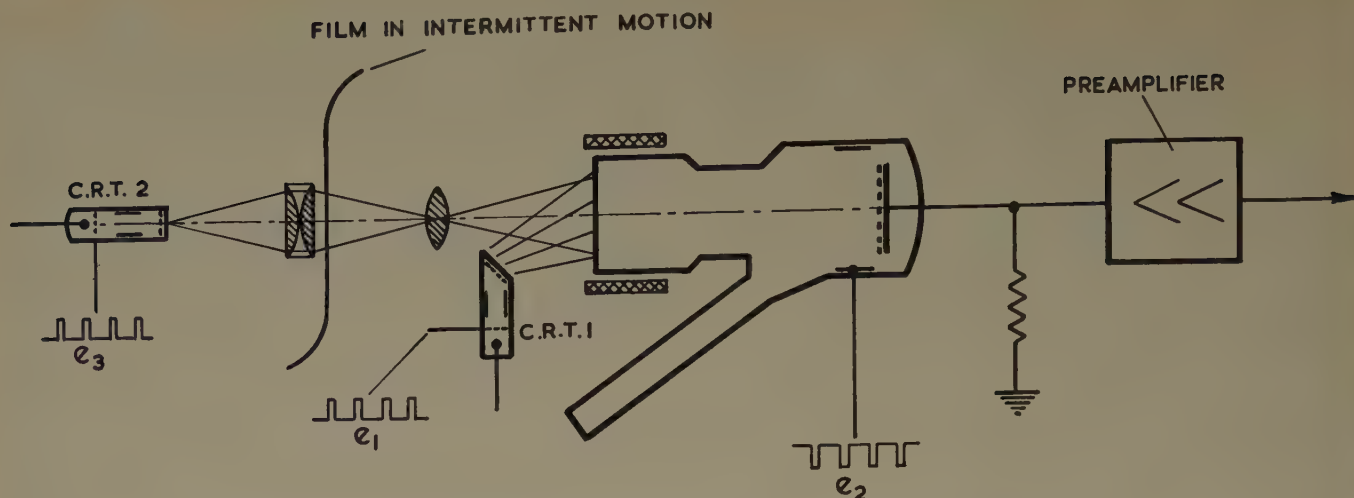


Fig. 4—Pulsed-bias operation of an image iconoscope for the television transmission of films.

restore the normal equilibrium condition, the negative potential shift being reinstated during the first period of the following cycle. The whole process is repeated at field frequency, e.g., 60 or 50 cps in normal television systems.

Fig. 4 also illustrates the use of a cathode-ray tube as a suitable light source for the intermittent picture projection. The control electrodes of the cathode-ray tubes CRT 1 and CRT 2 and the collector of the pickup tube are fed with voltage pulses in accordance with the sequence illustrated in Fig. 5. Between times 1 and 2 the charging process takes place, between 2 and 3 the picture projection, and between 3 and 1' the evaluation by scanning. Waveform  $e_1$  illustrates the pulses fed to the control electrode of CRT 1,  $e_2$  the pulses fed to the tube collector, and  $e_3$  the pulses fed to the control grid of CRT 2 to control the light-projection source.

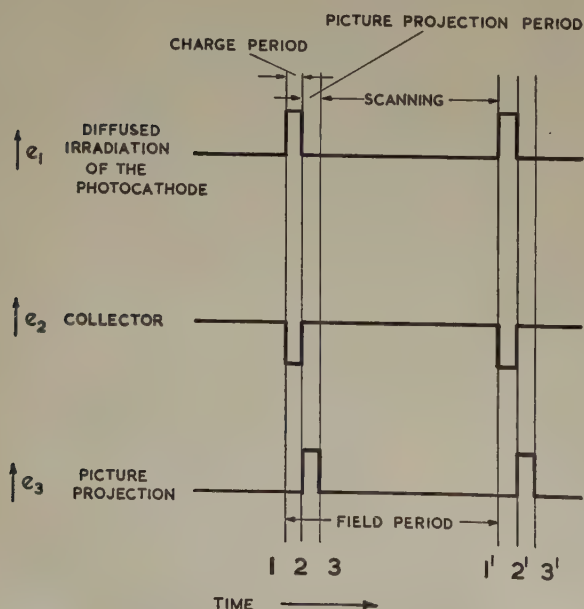


Fig. 5—Timing sequence of voltage pulses shown in Fig. 4.

#### ANALYSIS OF THE OUTPUT SIGNAL OF PULSED-BIASED IMAGE ICONOSCOPES

As only the general character of the produced signal is of interest at this stage, second-order effects, such as those due to the redistribution of residual secondary electrons, incomplete charge evaluation, and the like, are neglected during the first part of the following analysis, but are discussed at a later stage.

Consideration is first given to the application of the pulsed-bias technique for the transmission of cinema films, as outlined in Fig. 4. The signal-plate current waveforms, illustrated in Fig. 6, are obtained when transmitting an evenly illuminated field at different light levels: section (a) showing the current waveform obtained with no illumination (dark field), section (b) with medium-intensity illumination (gray field), and section (c) with high-level illumination (white field).

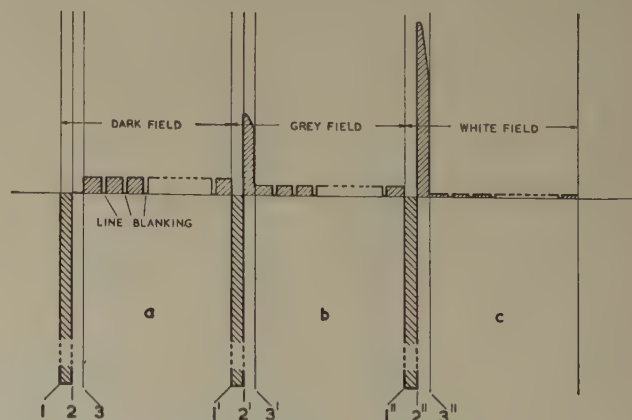


Fig. 6—Schematic-output waveforms from a tube operated as shown in Fig. 4 (intermittent picture projection).

During the charging intervals, 1-2, 1'-2', 1''-2'', there is present only the primary current originating from the pulsed photocathode or other source as all secondary electrons are returned to the storage surface. This charge current is plotted in a negative direction

since the resulting voltage developed at the amplifier input is negative relative to ground. During interval 2-3 (Fig. 6(a)) there is no signal-plate current owing to the absence of any photocathode illumination (dark field). It is only during the scanning interval 3-1' that electrons can reach the collector by secondary emission, thus producing a positive-going signal-plate current, interrupted during the line-blanking intervals. Negative-going pulses similar to those occurring during interval 1-2, are also developed during intervals 1'-2' and 1''-2''.

The conditions of grey field, illustrated in Fig. 6(b), are different, as during the picture-projection interval 2'-3' a positive-going pulse is developed as a result of secondary emission due to photoelectron bombardment of the storage surface. In consequence of the partial discharge of the storage capacity, the amplitude of the signal developed during the subsequent scanning process 3'-1'' is lower than that developed under dark field conditions.

During transmission of the brightly illuminated field (Fig. 6(c)) the surface is almost completely discharged to the normal collector potential in the picture-projection period 2''-3'', and the amplitude of the signal developed during the subsequent scanning period 3''-1''' is small.

In order to obtain the described results, it is important that the scanning-beam current is so adjusted that, in all cases, the total charge is completely evaluated. In other words, the mean signal current per picture element must have a direct relationship to the element charge.

The electron charges arriving at and leaving the storage surface must balance; therefore, as the charge is equal to the time integral of the current, it is necessary that the area equivalent to the negative-going pulses, as indicated in Fig. 6, shall, over a complete period, equal the total of the areas equivalent to the subsequent positive-going pulses. The distribution of the positive part of the signal between the picture projection and the scanning interval will vary according to the average light flux of the scene to be transmitted. As the amplitude of the signal during scanning decreases with increasing light level, the sense of the signal is negative, that is, it is of similar polarity to that obtained during normal operation of this type of tube. This makes it possible to introduce a continuous change from normal- to pulse-operated conditions.

It may be seen from Fig. 6 that information regarding the mean level of picture brightness is included in the picture signal when referred to the interline (zero beam) level. This unidirectional nature of the signal is due to the existence of the heavy counter-going pulse during the charging (nontransmission) period. The dc information is retained during the passage through an RC coupled amplifier if the well-known principle of dc restoration is used with reference to the line-blanking interval signal.

Although the mode of operation has been explained in conjunction with Fig. 6 for the transmission of pictures in the form of evenly illuminated fields only, it applies equally to fields of irregular light distribution. During the picture-projection interval, a charge pattern is developed on the storage surface and an average current flows corresponding to the integral of the elementary currents over the whole storage plate. The scanning process subsequently erases the remaining charge, thereby producing the varying signal current; periodically interrupted by the line blanking, the level during the blanking intervals corresponding to peak white.

As explained above, the beam-current density must be high enough to discharge every picture element completely. This means that some redistribution always exists, as, at least during the final part of the discharge process, some secondary electrons are returned to the storage surface. Fortunately, no serious disadvantages are caused by this residual redistribution, because the tendency of the secondaries to migrate in the direction opposite the direction of motion of the scanning beam is even greater under pulsed-bias operation than under normal operating conditions. Consequently, the secondary electrons do not disturb the charge pattern of those parts of the storage surface yet to be scanned, and any nonuniformity of the redistributed charge landing behind the beam is eliminated during the following pulse-charge interval, which precedes the next impression of the picture-charge pattern and scanning process.

There is also some redistribution during the picture-projection period, mainly towards the end of it, as areas which correspond to bright parts in the scene assume nearly the equilibrium potential. This can reduce slightly the storage efficiency, and may also cause some local variations in the picture contrast.

In order to obtain maximum efficiency and advantage of the pulsed-bias method of operation, it is desirable to keep the residual redistribution to a minimum. The surface-potential shift, established during the pulse period, should therefore be as high as possible. However, limitations are placed upon this requirement as the potential pattern amplitude on the storage surface has to be kept within a limited range in order to avoid second-order effects, such as those due to chromatic aberration in the focusing of the image and scanning electrons, deflection of the electrons by transverse fields, and the like. Fortunately, these limitations do not seriously restrict the application of pulsed-bias techniques.

With the restricted voltage range of each storage element, the amount of charge which can be stored depends on the element capacity. The suitable choice of the storage-plate capacity is now determined by the average light which is available in the scene, on which depend the average number of photoelectrons and, consequently, the average charge to be stored. For operation at low light levels, for example, small storage capacities are preferable in order to reach the desirable maximum

potential change with the low photocurrent available. The optimum beam current is then also small. On the other hand, if high light levels are available, it is preferable to use relatively large storage capacities which can retain a larger charge in the same permissible voltage range. It then becomes possible to obtain very strong output signals with negligible noise content under these conditions, which is an important advantage of the proposed method of operation.

The introduction of pulsed-bias operation modifies the transfer characteristic (signal output against light input) from that which is normal in high-velocity scanned tubes. The initial portion of the transfer characteristic is made more straight and the level at which output limitation occurs extends to higher values of light level, with increasing degree of potential shift. The half-tone rendition, as seen on a normal television receiving tube, is consequently different from that obtained under normal operation. If a high degree of biasing is applied, it may be necessary to "de-gamma" the signal in the following amplifier, as is required for flying spot scanners and Orthicon and image-Orthicon pickup tubes.<sup>18,19</sup> The variations of the transfer characteristic with the operating conditions are very similar to those obtained from the image Orthicon, the shift of the storage surface potential corresponding to the change of the mesh potential.

The analysis of the signal output makes it clear that under pulsed-bias operation the average signal amplitude is considerably smaller than the charge and discharge pulse amplitudes (see Fig. 6). It is therefore necessary to eliminate the peak pulse signals by suitable clipper circuits before or in the first stage of the pre-amplifier following the camera tube, otherwise the system would be overloaded and the useful signal distorted. This can be easily carried out by known methods.<sup>16</sup>

As explained, the interline pulses of the picture signal current correspond to peak white. This level is therefore not very suitable as an interval in which the "clamp circuit" for dc restoration is effective, as the real black level, although in fixed relation to these interline pulses, (see Figs. 6 and 8), will vary with changes in bias light pulses, in beam current, and the like. It is preferable to provide a restoration reference level corresponding to true black anywhere in the blanking period where the clamp circuit operates. This can be done by inserting a black strip at the left-hand side of the picture, which, of course, must be scanned before the picture blanking is ended. This requires that the camera-tube line-deflection retrace time be shorter than the picture-blanking time. The clamp circuit, effective only for a short period immediately before the actual

commencement of the line scanning, then holds the black level from which the picture signal is developed in a unidirectional sense (Fig. 6).



(a)



(b)



(c)

Fig. 7—Television pictures produced by the "Photicon" camera tube under intermittent projection conditions: a. With "pulsed bias" applied. b. As (a) with pulses removed, showing reduction of signal amplitude. c. As (b) with gain increased to obtain signal amplitude comparable with (a) showing marked presence of flare.

<sup>18</sup> T. C. Nuttal, "Some aspects of television-circuit technique: Phase correction and gamma correction," *Bull. schweiz elektrotech. ver.*, vol. 40, pp. 619-622; August, 1949.

<sup>19</sup> C. L. Townsend and E. D. Goodale, "The orthogam amplifier," *RCA Rev.*, vol. 11, pp. 399-410; September, 1950.

Fig. 7 illustrates some of the results obtainable by the application of pulsed-bias operation. In Fig. 7(a) is shown a television picture produced with intermittent picture projection under pulse-bias conditions. Fig. 7(b) shows the picture produced when the biasing pulses are removed, all other operating conditions remaining unchanged. From comparison of these two pictures it may be seen that, in addition to the other advantages claimed, pulsed-bias operation results in increased signal output from the camera tube. This gain is normally of the order of two to three times, considerably improving signal-to-noise ratio in the picture. Higher gains may be obtained by using a greater amplitude of biasing; however, this would probably make it necessary to "de-gamma" the picture, and may also introduce additional spurious signals, such as those arising from local variations in secondary-emission ratio. The results shown are obtained under the best compromise conditions. By increasing the amplifier gain so that the picture amplitude is similar to that shown in Fig. 7(a) the presence of edge flare, which exists under normal operating conditions, becomes more easily observable. This is shown in Fig. 7(c).

The conditions of operation during the transmission of continuously illuminated scenes, as required for live pickup, are more complicated than those during transmission of intermittently projected film, as considered so far. These complications are due to the fact that the charge-pattern development (picture projection) and scanning processes occur simultaneously. One complete frame period consists of two intervals only—pulse charge and scanning.

To analyze the picture signal under these conditions we first assume that during the pulse-charge interval the storage plate is charged to an even potential across its whole surface, any residual charge pattern being erased. The complete signal output of the tube may be analyzed into three separate components. Fig. 8(a) shows the charge current which occurs only during the pulse-charging interval, and consists of a succession of negative pulses at frame frequency. The second component, illustrated in Fig. 8(b), represents the integrated electron current from the storage surface due to secondary emission by photoelectron bombardment. The amplitude of this current decreases during the frame period owing to the time decay of each individual discharge process and owing to the fact that the process of scanning progressively reduces the area of the surface which has not been brought to the equilibrium potential. The shape of the waveform of this component is affected by the degree of potential shift that is, whether or not the secondary emission is saturated. The third component (Fig. 8(c)) is the signal due to the scanning process. This signal shows a change in depth of modulation during the frame period as the storage time is very short at the commencement of the frame-scanning period, but increasingly longer as the scanning proceeds. Therefore, the signal-plate current

is high at the commencement of frame deflection whatever the picture content, but with increasing time the current may approach zero if areas corresponding to white areas in the picture are scanned.

Fig. 8(d), shows the actual signal current resulting from the combination of the three components Fig. 8(a-c). Two shortcomings are apparent, namely, the changing base line and the change in modulation depth. It is relatively easy to eliminate the first-mentioned additive component (Fig. 8(b)) as the signal has periodic interruptions during the line-blanking time, the level of which can be used as a reference level for a clamped dc restorer in the amplifier chain in the same manner as other low-frequency distortions, hum, and the like are suppressed. It is only necessary that those stages of the amplifier preceding the dc restoration have a linear transmission range sufficiently wide to avoid distortion of the signal.

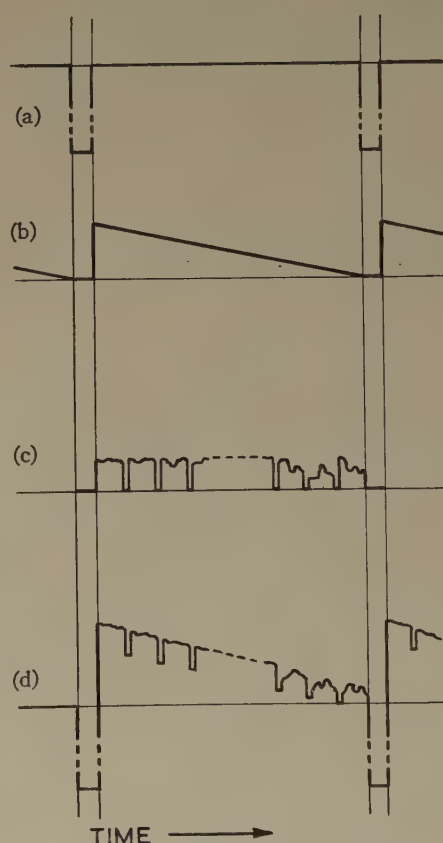


Fig. 8—Schematic-output waveforms from a pulsed-biased image iconoscope under continuous pickup conditions.

The second shortcoming, due to change in depth of modulation, is of much greater importance, and means that no satisfactory signal can be obtained under the assumptions made.

In spite of this, experiments showed that usefully improved pictures can be obtained provided that the potential shift is limited to a low value. This is found

to be sufficient to reduce the spurious signals and flare, to give the signal a more unidirectional character, and to balance the slight decrease in the depth of modulation from top to bottom of the picture which occurs under normal operating conditions due to nonuniformity of redistribution.

These results indicate that the lack of charge-pattern development during the early part of the picture period is not as serious as was assumed. Investigations show that this is because the storage time in the tubes under consideration is usually shorter than the frame period. Therefore, by making the charge pulse as short as possible and timing it to occur at the beginning of the frame-blanking interval, the remaining part of this interval is sufficient to build up an appreciable charge pattern at the top of the picture before scanning commences. There still remains a modulation of the signal during the scanning period, but this can be equalized by an inverse modulation of the amplifier gain.

It is also found that an indirect method of charging the storage surface helps to preserve at the top of the picture the charge pattern developed during the preceding frame period. One method of performing this indirect charging is to mask the photocathode so that the pulse illumination does not irradiate the area on which the picture is projected. Instead it irradiates only the adjacent areas, those which mainly surround the bottom part of the picture where the disturbing flare shows up most under normal operation. The process of storage-plate charging occurs by redistributing secondary electrons from the neighboring bombarded areas. These results are not surprising in view of those obtained from bias light technique with memory scanning in iconoscope film scanners,<sup>14</sup> where a potential shift is obtained from the continuous landing of low-velocity photoelectrons at the storage surface which have no appreciable influence on the picture-charge pattern, but impart only an additive charge. A suitable method of carrying out the indirect method of pulse charging is by the insertion of a funnel between the camera lens and the photocathode. This is so formed that it frames the picture area and masks it from illumination by the pulse light source. Experiments with intermittent picture projection in which the phase of the projection relative to the scanning interval is adjustable, indicate that with such an indirect method of charging the shape of the picture-charge pattern is retained to a useful degree after the charge pulse has taken place.

### CONCLUSIONS

The described "pulsed-bias" technique improves the operating characteristics of image-iconoscope camera tubes by simple means. Experimental results are in close agreement with the given analysis, and show that the major faults of these tubes are eliminated or considerably reduced: Flare and "dark spot" are brought to low levels, no adjustments to the shading controls are re-

quired during operation, a unidirectional sense of the output signal is obtained, and with suitable dc restoration in the amplifier, the constancy of black level is well maintained. A further important feature is that, owing to the improved efficiency of signal generation, the output signal amplitude, and consequently the signal-to-noise ratio, are increased by about two to three times.

The full advantages of the technique are obtainable on the transmission of intermittently projected pictures, such as "memory-scanned" cinema films. For continuous pickup, only partial application of the technique is possible. Although the improvements so obtained are appreciable, the practical use of this technique is doubtful as other methods of bias application, now under development, show promise of better results. It is hoped that a report on this work will be published in the near future.

Provision for the pulsed-bias method of operation can be easily incorporated in image-iconoscope camera equipment so that the same tube may be used biased for film transmission and unbiased or partially biased for direct pickup (studio) use. This meets the long-established requirement for a camera tube able to give satisfactory service for both purposes, and the possibility of more flexible equipment utilization is thereby increased, bearing in mind that modern versions of the image iconoscope, such as the Photicon, are giving highly satisfactory results as studio and outside broadcast pickups in Great Britain and other European countries.

Results obtained on tests and in service for film transmission compare favorably with those obtained from other high-quality devices, such as flying spot scanners and image dissector tubes.

Apart from the improved equipment utilization, the use of a camera tube in conjunction with standard (synchronized) cinema projectors for the televising of films allows stationary film to be viewed, which means that single frame captions may be transmitted or pictures may be previewed for adjustment or other purposes.

The pulsed-bias technique as described has been incorporated in telecine equipment manufactured for the British Broadcasting Corporation by Pye Ltd. of Cambridge, England, utilizing the "Photicon," a British-made camera tube of the image-iconoscope type.

### ACKNOWLEDGMENTS

The investigations were carried out in the Laboratories of Pye Ltd. and Cathodeon Ltd., both of Cambridge, England, and the authors wish to express their thanks to the directors of these companies for permission to publish these results. Thanks are also due to many of their colleagues for suggestions, criticisms, and assistance, and to R. W. Lee of General Precision Laboratories, Pleasantville, N. Y., for helpful discussions.

# The $Q$ of a Microwave Cavity by Comparison with a Calibrated High-Frequency Circuit\*

HUGH LECAINE†

**Summary**—A comparison method has been developed for the direct measurement of cavity  $Q$  at microwave frequencies. It is particularly useful for high values of  $Q$ , such as 5,000 to 15,000. The over-all error in the measurement is estimated to be less than  $\pm 3$  per cent.

A two-channel superheterodyne technique is used, in which both channels are driven by the same frequency-swept oscillator, and both channels use the same local oscillator. The cavity is inserted in the radio-frequency stage of the first channel, and a comparison circuit is inserted in the intermediate-frequency stage of the parallel channel.

The two resonance curves are displayed on the same oscilloscope for alternate sweeps of the oscillator. When the resonance curves are made to coincide, the  $Q$  of the cavity is  $n$  times the  $Q$  of the comparison circuit, where  $n$  is the ratio of radio frequency to intermediate frequency.

Cavity shunt resistances can be measured on the same apparatus.

## I. THE METHOD

**M**OST PRACTICAL methods of measuring the unloaded  $Q$  of a cavity follow either one of two basic procedures: (1) The relative energy transmitted through the cavity is measured over a range of frequencies including the resonant frequency, using extremely loose coupling both in and out. (2) The impedance looking into the cavity is measured over a similar range of frequencies.

Sproull and Linder<sup>1</sup> followed the first procedure, sweeping through the range of frequencies automatically with a "frequency-swept" klystron oscillator, and recording the transmitted energy on an oscilloscope. Then the  $Q$  was determined from the resulting "resonance curve" by observing the spread in frequency between half-power points. The method described below is essentially that of Sproull and Linder, with the addition of a variable "comparison curve" displayed on the same oscilloscope and taken from a high-frequency resonant circuit of variable  $Q$ . The result is a considerable increase in the accuracy of the measurement, particularly when the  $Q$  of the cavity is high.

A two-channel superheterodyne technique is used in which both channels are driven from the same frequency-swept oscillator, and both channels use the same local oscillator as shown in the block diagram of Fig. 1. The cavity is inserted in the radio-frequency stage of the

first channel, and the comparison circuit is inserted in the intermediate-frequency stage of the parallel channel. Then any increment in frequency at the cavity is identical with the resultant increment in frequency at the comparison circuit.

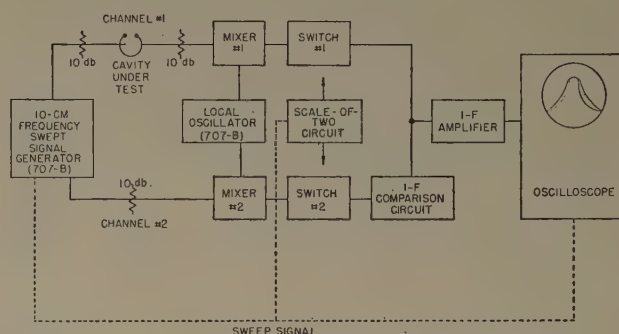


Fig. 1—A block diagram of the two-channel superheterodyne  $Q$  measuring setup.

The two resonance curves are displayed on the same oscilloscope for alternate sweeps of the oscillator, and the  $Q$  of the comparison circuit is varied until the two curves come into coincidence. Then the spread in frequency between the half-power points on one curve will be identical with that on the other, while the resonant frequencies will be in the ratio  $n$ , where  $n$  is the ratio of radio frequency to intermediate frequency. Hence the  $Q$  of the cavity will be  $n$  times the  $Q$  of the comparison circuit.

The equipment was required to measure the  $Q$ 's of cavities resonant at about 2,800 mc, and it was decided to design for a range of  $Q$ 's from 5,000 to 15,000. An intermediate frequency of 19.5 mc was selected so that  $n$  equalled 144. Thus the required range of  $Q$ 's for the comparison circuit is about 35 to 105. Such a range of values is readily realized at 19.5 mc in an accurately calibrated variable  $Q$  circuit.

## II. THE ADVANTAGES

The outstanding advantage of the comparison method of measuring cavity  $Q$ 's is a decided increase in the accuracy of interpreting the display on the cathode-ray tube, particularly when the  $Q$  is very high. In the single resonance curve method, the difference in

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<sup>1</sup> R. L. Sproull and E. G. Linder, "Resonant cavity measurements," *Proc. I.R.E.*, vol. 34, pp. 305-312; May, 1946.

frequency at the half-power points must be read from the face of the tube, and when the  $Q$  is very high this difference may be less than a scale division on the wavemeter. For example, the difference in frequency is only 280 kc for a  $Q$  of 10,000 at a resonant frequency of 2,800 mc.

Montgomery<sup>2</sup> has described a heterodyne system of producing two markers or pips which may be set at the half-power points. The difference in frequency between the two pips can be determined with great accuracy, but the error in determining the half-power level is still considerable. In any case, the over-all error in the single resonance curve method is seldom less than  $\pm 7$  per cent.

In the comparison method the cathode-ray tube is used simply to bring the two resonance curves into coincidence between the half-power points. Complete coincidence below the half-power points is not always possible, since the two resonance curves are not quite identical in shape. The error introduced at this point is approximately the ratio of spot diameter to one-half the face diameter, or about  $\pm 1$  per cent.

In addition, the comparison method has several lesser advantages over the single resonance curve method, each contributing to the over-all accuracy of the measurements.

(1) Since the superheterodyne detector is highly sensitive, it is extremely easy to make the coupling both into and out of the cavity much smaller than necessary to avoid cavity loading effects.

(2) The response-law of a crystal used as a first detector in a superheterodyne circuit is much more reliable than that of a crystal used as a simple detector. The response-law of the second detector does not matter, since it is common to both systems.

(3) The two mixers are separate in the two channels, and must be similar; but all other components are common and affect both curves equally. Hence there are no close restrictions on distortion in the oscilloscope, distortion in the amplifier, or amplitude and frequency modulation of the swept oscillator.

The over-all error for the comparison method, measuring  $Q$ 's of about 10,000, is estimated to be less than  $\pm 3$  per cent.

### III. THE MEASUREMENT OF SHUNT RESISTANCE

The shunt resistance of a cavity can be measured on the same equipment by the "capacitance insertion" or "resistance insertion" method. In the first case, a small dielectric cylinder is placed in a suitable position in the cavity and the shunt resistance is calculated from the resultant change in resonant frequency. The method is essentially that of Sproull and Linder,<sup>1</sup> but uses a

superheterodyne technique with one outstanding advantage.

The absolute difference in frequency is exactly the same in the radio- and intermediate-frequency stage, where its value relative to the mean frequency is very much greater. A small signal from a calibrated signal generator may be inserted in the intermediate-frequency stage, to appear in the output as a zero-beat marker superimposed upon the resonance curve. The marker may be set on the peak of the resonance curve, or on some point on the side of the resonance curve, both before and after insertion of the dielectric cylinder, and the difference in frequency noted.

The cavities under test at the National Research Council were for use with tunable magnetrons in an experimental electron accelerator. Thus, there was no need for a precise measurement of the resonant frequency, and this problem was not considered.

### IV. THE COMPONENT PARTS OF THE INSTRUMENT

#### A. The Frequency-Swept Oscillator

Any oscillator capable of being swept over the required frequency range may be used. The frequency change need not be any particular function of the applied voltage, since in any case the same sweep is applied to both channels. In the 10-cm band, the 707-B klystron is a suitable tube.

#### B. The Mixers

The two mixers should be as nearly identical as possible, using simple untuned circuits, and matched crystals.

If the cavity is replaced in the first channel by a flat attenuator with the same insertion loss, and if the comparison circuit is removed from the other channel, then the two channels will be identical except for whatever differences there may be in the two mixers. If the two curves obtained on the oscilloscope under these conditions lie together over the required frequency band, then the mixers are satisfactory.

#### C. The Switches

The switches are used to present the resonance curve of the cavity and that of the comparison circuit on alternate sweeps of the same oscilloscope. They consist of two 6AC7 tubes biased to cutoff on alternate sweeps. The divider circuit is a standard "scale-of-two" circuit, triggered by a pulse derived from the sweep generator in the frequency-swept oscillator. A change in gain from "off" to "on" of zero to 40 or 60 db is realized readily, and this is more than adequate since the two curves are adjusted to coincide in any case.

<sup>2</sup> C. G. Montgomery, "Techniques of Microwave Measurements," Radiation Laboratory Series, vol. 11, pp. 396-407; McGraw-Hill Book Co., Inc., New York, N. Y.; 1947.

### D. The Comparison Circuit

The comparison circuit is a simple coil and condenser combination with a variably coupled loading resistor in shunt, as shown in Fig. 2. The  $Q$  of the circuit without the loading resistor must, of course, be higher than the highest  $Q$  required for comparison purposes. Then any required  $Q$  may be realized by simply varying the coupling of the loading resistor.

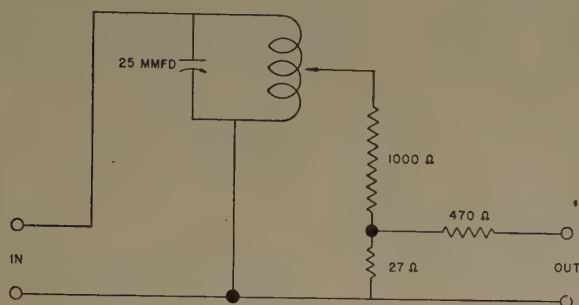


Fig. 2—The "comparison" circuit in the intermediate-frequency stage.

It is highly desirable for simple operation that the loading resistor should change the  $Q$  of the circuit without detuning it, and thus it should be relatively nonreactive. Hence the capacitance in the comparison circuit should be quite large so as to minimize the effect of the natural shunt capacitance across the resistor. A suitable value was realized for a range of  $Q$ 's from 35 to 500 at 19.5 mc, when the capacitance was adjusted to give the circuit a resonant impedance of about 1,000 ohms with the coupling of the loading resistor set to give a  $Q$  of about 200. At the same time, the loading resistor itself should be selected for minimum inductance. Carbon resistors were found unsuitable because of their poor temperature characteristics. A specially built noninductive, wire-wound resistor was finally selected for this purpose.

It has been found that such a comparison circuit holds a calibration exceedingly well, chiefly because there is very little drift in the value of the loading resistor. Suitable calibrating gear has been built into the setup.

In calibrating the comparison circuit the  $Q$  is measured for a large number of separate couplings of the loading resistor, and the equivalent  $Q$  of the cavity is marked directly on the coupler scale, thus making the instrument direct reading. For any particular coupling, the  $Q$  is determined by measuring the difference in frequency between the half-power points on the resonance curve of the comparison circuit, using a frequency-calibrated signal generator with the frequency of the output controlled manually.

The output from the signal generator is fed through an automatic-gain-controlled 19.5 mc amplifier to the

grid of the 6AC7 switching tube, as shown in the block diagram of Fig. 3. The output of the amplifier remains constant as frequency is varied, but may be set as required at either a "peak" (full) output, or a "0.707" (3 db down) output. First the resonance point is found with the amplifier output set at "0.707" by adjusting the frequency for a maximum signal from the diode across the comparison circuit. Then the amplifier output is switched up to "peak" and the signal from the diode across the comparison circuit is brought back down to its former value by detuning the signal generator, thus determining the first of the two half-power points. The other one is found by detuning in the other direction. The frequency at each of the two half-power points is read directly from the signal generator.

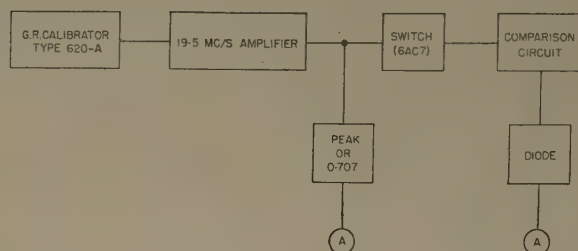


Fig. 3—A block diagram of the calibration circuit.

The response-law of the diode across the comparison circuit is of no importance, since the diode output is brought to the same value for all readings.

The measurement takes into account all frequency-sensitive elements from the plate of the switching tube to the junction point of the two channels. It does not take into account slight variations in impedance with frequency in the grid circuit, which must balance similar variations in the other channel, as explained above under "The Mixers."

The General Radio "Calibrator" Type 620-A was found to be an exceedingly satisfactory signal generator for calibrating the comparison circuit. It uses a 1 mc crystal for checking each of ten 1 mc bands, including the band required here.

### E. The Intermediate-Frequency Amplifier

The intermediate-frequency amplifier is of standard construction. It was designed for a bandwidth of about 7 mc, so that a wide frequency sweep could be used in setting up a new cavity. Since this amplifier is common to both channels, its design is not critical.

An intermediate frequency of 19.5 mc was selected because it lies in the middle of one of the bands of the General Radio "Calibrator" Type 620-A used in calibrating the comparison circuit.

# A Homopolar Tachometer for Servomechanism Application\*

CRAIG C. JOHNSON†

**Summary**—Certain design considerations, construction detail, and performance data are presented for a small disk-type homopolar tachometer which was developed as a low inertia, low noise, low friction rate signal source for incorporation into a high-performance servomechanism. Performance characteristics reveal that a unit of this type has certain advantageous features which recommend it over conventional tachometers, although a low signal output level is an inherent disadvantage.

FOR CERTAIN high-performance servomechanism and electromechanical analog computer systems in which it is necessary to obtain a voltage proportional to a shaft rate (wherein this quantity is used for feedback and/or intelligence), it is desirable to have available a low inertia, low friction tachometer, the output signal of which is linear with the input shaft rate. It is also desirable that the electrical noise components in this output signal be held to a minimum. The attainment of these characteristics in a tachometer will enhance the performance of the servo system under both static and dynamic conditions. Commutator ripple and relatively high brush friction associated with permanent magnet and other dc generators are generally undesirable. AC drag-cup induction generators, though mechanically satisfactory, present problems because of electrical phasing difficulties, residual voltage effects, harmonic content in the generated signal, and rectification and filtering in such systems where a dc output is required. The homopolar tachometer described in this paper was developed as a component in a high-performance servo system in an attempt to circumvent some of the above-mentioned difficulties.

The principle of the homopolar generator is believed to have been discovered by Faraday, and may be stated simply, as follows: If a conducting disk is rotated between the poles of an annular magnetic field of constant strength, as indicated in Fig. 1(a), an emf is induced between the periphery of the disk and its center of rotation. The polarity of the induced signal is in accord with Lenz's law; thus by reversing the direction of disk rotation, the polarity of the induced signal is also reversed. No eddy-current damping will exist so long as the magnetic field is circumferentially homogeneous. In terms of the physical parameters of the conductor and magnetic field, the value of the induced voltage is given by the following expression:

$$E = \frac{\beta l \bar{v}}{10^8} \text{ volts,} \quad (1)$$

where

$\beta$  = magnetic-field intensity in gauss

$l$  = length in cm of conductor cutting magnetic lines of force

$\bar{v}$  = average velocity of cutting lines of force in cm/sec.

In as much as the output-voltage level for such a unit is characteristically low as compared to conventional tachometers of roughly the same physical size, it will usually be necessary to amplify this signal for system utilization. Because of this fact, and since a low disk moment of inertia will usually be desirable in a high-performance system, it follows that the output voltage/inertia ratio might be a useful criterion in selecting an optimum rotor-magnetic field configuration. Referring again to Fig. 1(a) and substituting appropriate values into (1), one finds the output voltage for this configuration to be

$$E = \frac{3}{8} \left( \frac{\beta \omega r_0^2}{10^8} \right) \text{ volts,} \quad (2)$$

where

$\omega$  = angular rate of disk rotation in rad/sec.

(It is assumed in (2) that  $r_i = r_0/2$  for a small disk in order to provide clearance for a shaft and supporting

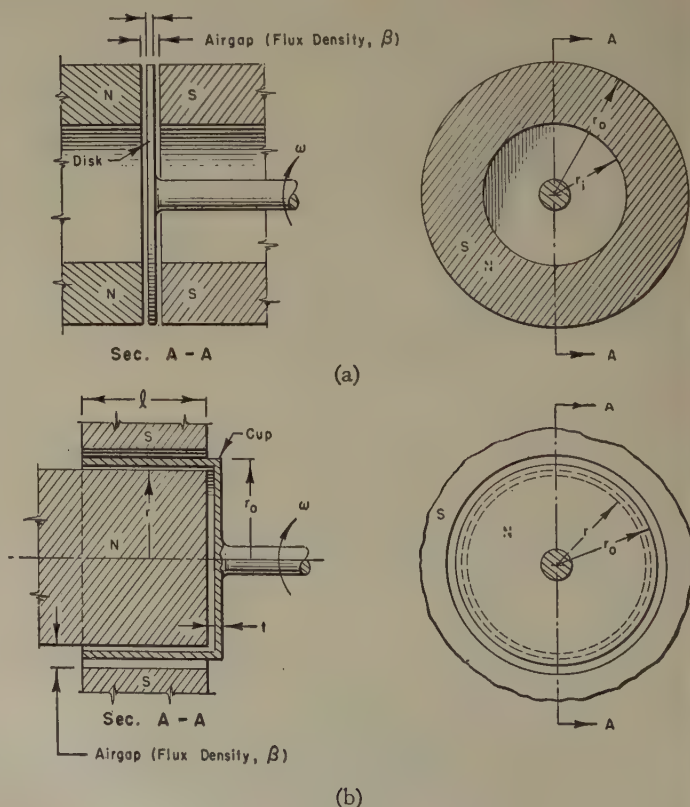


Fig. 1—Magnetic field—rotor configurations.

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bearings.) Then, assuming a solid disk of thickness  $t$  and density  $\delta$ , and neglecting the moment of inertia of the shaft and bearings, the output voltage/inertia ratio is given in appropriate units by

$$\frac{E}{J} = \frac{3}{4} \left( \frac{\beta \omega}{\delta \pi t r_0^2} \right) \frac{1}{10^8} \quad (3)$$

For purposes of comparison, the configuration shown in Fig. 1(b) will also be considered. This unit consists of a cup rotating in a radial magnetic field similar to the voice coil magnetic circuit used in most loud speakers. From the standpoint of good magnetic design, it will be assumed that

$$\pi r^2 = 1.2(2\pi r l).$$

For a narrow air gap, it will be valid to let  $r_0 \approx r$ , and it will be further assumed that  $t \ll r_0$ . Under these conditions, and letting  $\beta$ ,  $\omega$ ,  $\delta$ ,  $t$ , and the output voltage  $E$  be the same for the two configurations (i.e., the cup and the disk) it can be shown that

$$\left( \frac{E}{J} \right)_{\text{disk}} = 2.16 \left( \frac{E}{J} \right)_{\text{cup}} \quad (4)$$

Further analyses along these lines will reveal that the disk has an  $E/J$  higher than any other single-rotor configuration. Moreover, it can be shown that  $E/J$  for cascaded disks may be improved over that of a single disk by a factor equal to the number of disks in series, this conclusion being based on the comparison of two units of equal output voltage. However, the construction of a unit utilizing smaller disks in cascade would be rather elaborate and, since each disk requires brushes, it could be expected that higher friction and noise levels would result.

In view of the above results, together with the fact that a disk-type unit would be easier to fabricate, it was decided that such a unit as shown in Fig. 2 should be constructed. In order to reduce the size of the exciting

coil, the magnetic circuit was made of Allegheny 4,750 high-permeability alloy, which saturates around 10,000 to 11,000 gauss. With this value of  $\beta$ , the dimensions of the magnetic field were chosen so that the output voltage would be approximately 1 mv per rps. With an aluminum (24ST) disk 2 inches in diameter and 0.030 inch thick and a total air gap of 0.060 inch, it was found that a 1,500-amp turn coil would be required. A coil of 1,030 turns was layer wound of No. 20 Formex insulated wire. An exciting current of 1.5 amp dc essentially saturates the magnetic circuit and results in the dissipation of about 15 watts in the coil. The coil is electrically floating so that the polarity of the magnetic field may be reversed by switching the coil input leads.

As mentioned at the outset, low electrical noise and low mechanical friction are two important characteristics desired in a unit of this type. The quality of the electrical pick-off brushes will directly determine both the noise and friction levels. Generally, an increase in brush pressure will decrease noise and increase friction so that some compromise solution is required. For this unit, reasonably satisfactory performance for the peripheral contacts was achieved through the use of two brushes (shorted together) phased approximately 90 space degrees apart on the disk, a unique spacing which appeared to reduce chattering effects. The contacts consist of Paliney No. 7 bars soldered onto thin leaf springs which were over-damped with layers of scotch electrical tape. These contacts ride on a thin silver ring which was shrunk over the disk periphery. It was found necessary to lap the contacts and ring with fine abrasive in order to reduce output noise. For symmetrical performance with direction of disk rotation, it was found desirable to orient the leaf springs in opposition, as shown in Fig. 2. Brush pressure was adjusted for optimum results. Because of low rubbing velocities the center contact is not critical and consists merely of a spring bearing against a brass pin which is pressed into the disk center. It is apparent from Fig. 2 that the shaft

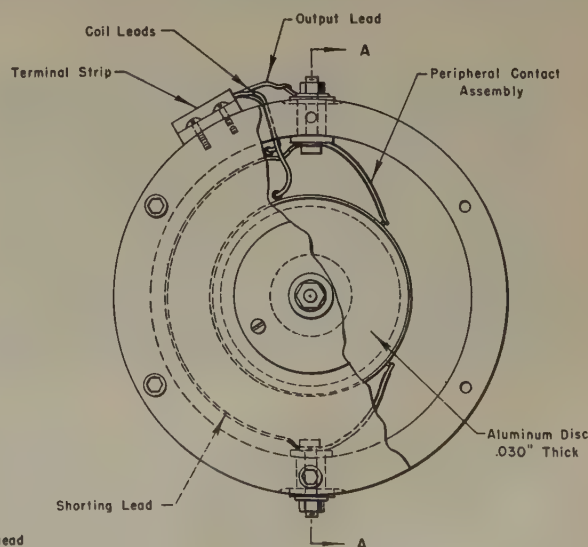
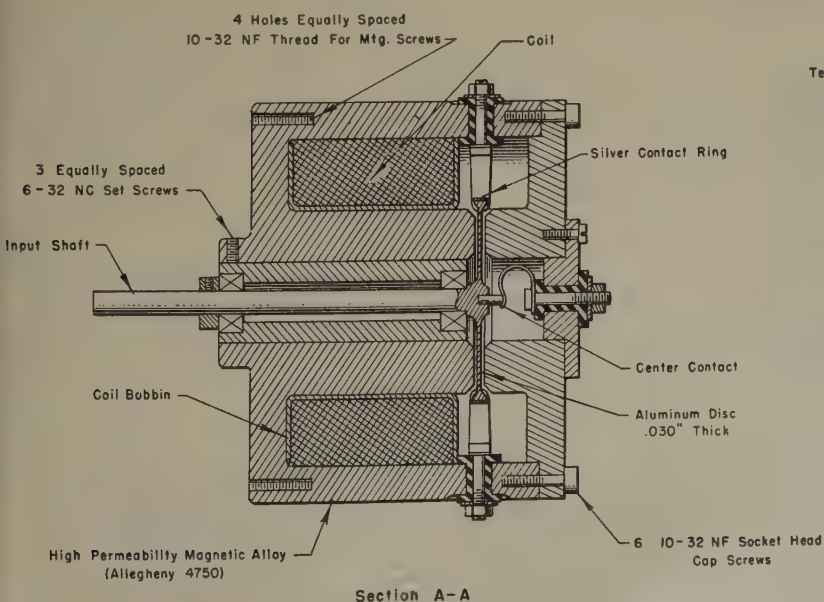


Fig. 2—Homopolar generator.

and disk are electrically grounded through the bearings to the case. Thus, the center contact serves only as a direct ground for eliminating bearing noise. It is possible, of course, through suitable insulation, to construct a unit with a double-ended output.

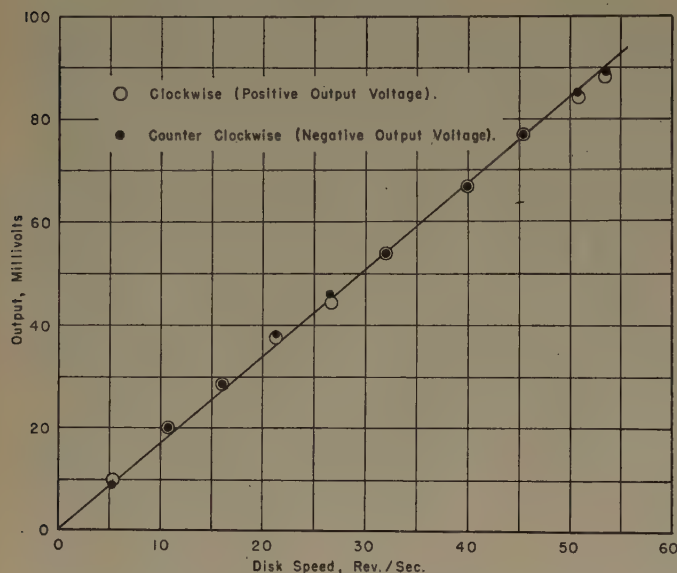


Fig. 3—Output volts versus speed at constant field current (1.5 amp dc).

Linearity of output voltage versus speed of rotation is indicated in Fig. 3. The output voltage is about 1.7 mv per rps, which is somewhat higher than design calculations. This may be attributed to the fact that magnetic fringing effects were neglected in these calculations. No attempt was made to measure the electrical time constant of the disk, but it is believed that it will not cause any effects below, for instance, 50 cps. The moment of inertia,  $J$ , of the disk equals  $2.5 \times 10^{-6}$  slug-ft<sup>2</sup> (where 50 per cent of this value is represented by the silver ring). Starting friction torque is about 0.4 oz. in.

The electrical noise present in the output is high frequency in nature, and its peak-to-peak value was found

to be less than 1 per cent of the signal voltage for all values of speed up to 3,200 rpm. The noise level was observed with the generator output feeding into the grid of an amplifier tube and filtered with a 0.01  $\mu$ f condenser. Current loading of the output materially increases the noise level so that a moderately high impedance load appears essential to satisfactory operation. The generation of thermoelectric potentials between the Paliney No. 7 brush contacts and the silver ring, due to frictional and coil dissipation heating, appears negligible since the output voltage versus speed curve (Fig. 3) is essentially symmetrical with direction of rotation. Appreciable thermoelectric potentials would bias the curve and destroy such symmetry.

The actual unit described above has been incorporated into the system for which it was designed. Performance of the unit in this system has proven qualitatively superior to the performance of other types of tachometers which were previously utilized. Operation has been essentially trouble free, except that it appears desirable to clean and relubricate the contact surfaces occasionally.

It is believed that the homopolar tachometer may be improved considerably for use with servomechanisms and related systems. A permanent magnet field, a reduced over-all size, and a mercury-pool electrical pick-off present intriguing possibilities. The major disadvantage of a low output signal level remains, however, thus necessitating the rather stringent requirements for low-drift, high-gain amplification.

#### ACKNOWLEDGMENT

This development, including fabrication of components, was performed at the Defense Research Laboratory, University of Texas, Austin, Texas, under the sponsorship of the United States Navy Bureau of Ordnance. The author is indebted to various members of the DRL staff for consultation and advice, and, in particular, to Charles W. Frobese upon whose suggestion this work was instigated.

## A Portable, Direct-Reading Microwave Noise Generator\*

E. L. CHINNOCK†

**Summary**—This paper discusses the factors which influenced the design of a directly calibrated portable microwave noise source, utilizing a fluorescent lamp.

THE USE OF the gaseous discharge in an ordinary fluorescent lamp as a source of microwave noise power has been suggested by Mumford. The uniformity and stability of these lamps make them attrac-

The variation of the noise power output and the impedance match as a function of the operating temperature are considered, and the portable unit is described.

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tive for use as a tool for the measurement of noise figures of microwave circuits.<sup>1</sup> There is, however, a slight temperature correction to be applied when the greatest accuracy is demanded. The unit to be described includes a convenient means of allowing for this correction.

<sup>1</sup> W. W. Mumford, "A broad-band microwave noise source," *Bell Sys. Tech. Jour.*, vol. 28, pp. 608-618; October, 1949.

A plot of the data taken on an early model shows the magnitude of this correction in Fig. 1. These data cover the operating temperature range from 30 to 50°C, as measured by a mercury thermometer placed in contact with the waveguide circuit surrounding the lamp. It is seen that the excess noise power increases by 1.1 db in this 20-degree range, corresponding to a negative temperature coefficient of  $-0.055$  db per degree C.

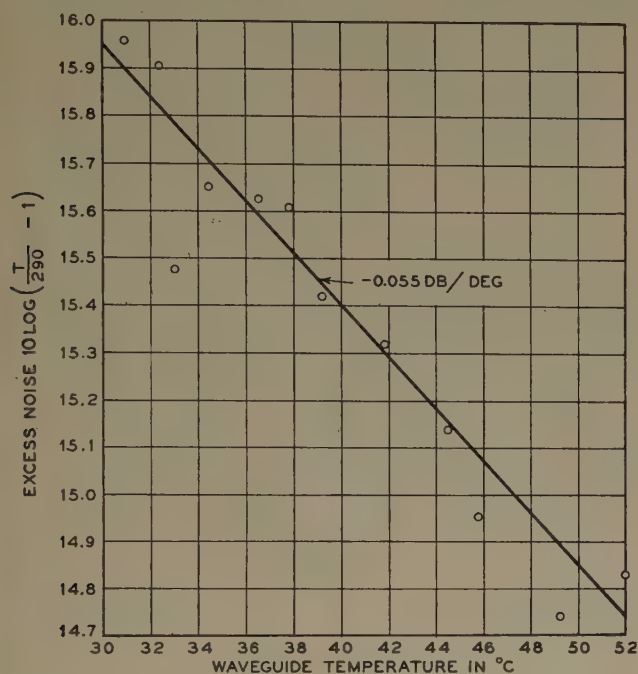


Fig. 1—Temperature coefficient of microwave noise source.

While this is a small coefficient, it was felt that we might do even better by operating at a lower temperature, since when the mercury is frozen out, the discharge would be characteristic of the remaining argon whose electron temperature (and hence microwave noise power

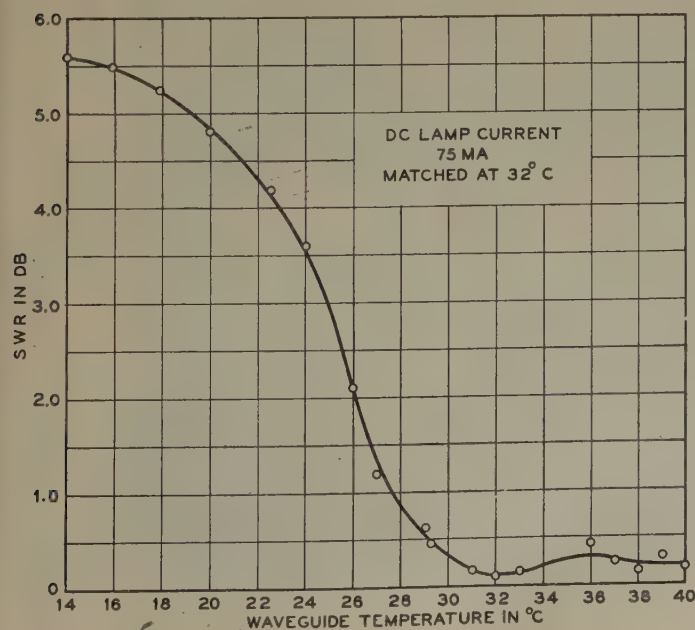


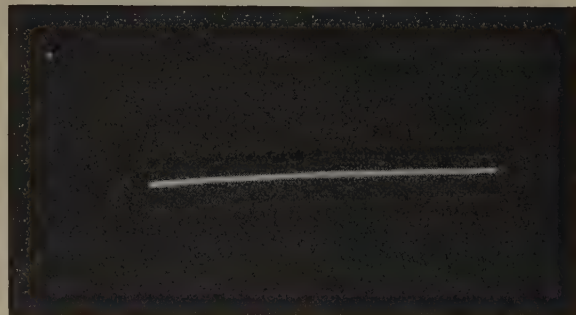
Fig. 2—Impedance match versus temperature.

output) might be less than that of the mixture of gases.<sup>2</sup> At some intermediate temperature, the coefficient should be zero.

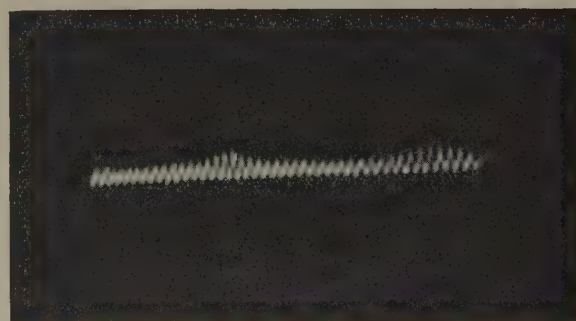
Such a region was sought and found, but unfortunately the microwave impedance match to the waveguide became worse as the temperature was lowered, as shown in Fig. 2. For these data, the lamp was matched to the waveguide at 32°C and the average reflection coefficient was noted, using a directional coupler in a match meter. This was interpreted in terms of standing-wave ratio for plotting along the ordinate. Efforts to re-match the lamp at the lower temperatures met with no success, which suggested that the impedance was not remaining constant. Using an oscilloscope to observe the reflection coefficient as a function of time, the patterns shown in the photographs of Fig. 3 were obtained. Fig.



(a)



(b)



(c)

Fig. 3—Reflection coefficient versus time displayed on an oscilloscope. (a) temp=14°C, 1,500~sweep, avg w 10.3db, avg SWR—5.7db, IF atten 25db. (b) temp=31°C, 1,500~sweep, avg w 42.0db, avg SWR—0.14db, IF atten 25db. (c) temp=31°C, 60~ sweep, avg w 42.0db, avg SWR—0.14db, IF atten 0db.

<sup>2</sup> H. Johnson and K. R. De Remer, "Gaseous discharge super-high-frequency noise sources," *Proc. I.R.E.*, vol. 39, pp. 908-914; August, 1951.

3(a) shows that at 14°C the reflection coefficient varied with time cyclicly at a frequency of a few kilocycles. Figs. 3(b) and (c) show that at 31°C these effects were reduced. In Fig. 3(c) the receiver gain was 25 db greater than in Figs. 3(b) and (a), revealing that the oscillations were still present, though negligible. From the data of Figs. 2 and 3, it was concluded that if a good match was desired, operation of the lamp should be confined to ambient temperatures above 28°C, measured at the waveguide.

In the course of these measurements, evidence of considerable time lag was observed in the mercury thermometer indication, and it was thought that this could be reduced if the temperature at the lamp itself could be measured. Several means for measuring temperatures are possible. A thermocouple would involve the maintenance of some kind of constant temperature bath. Mechanically indicating thermometers would be too bulky and would lack the speed and accuracy desired. Since a resistance thermometer has many attractive features, it was tried. Fig. 4 shows a temperature

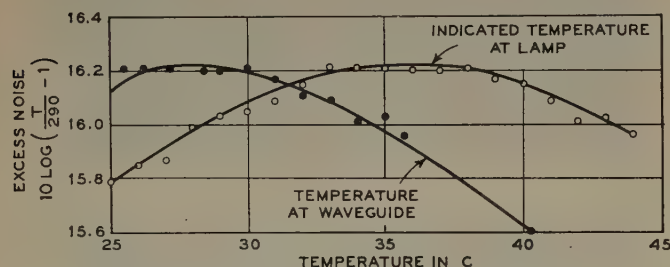


Fig. 4—Excess noise output versus temperature.

run on one lamp as the ambient temperature was changed. One curve is for the mercury thermometer mounted on the exterior waveguide; the other is for the resistance thermometer mounted directly on the lamp. The predicted maximum in the excess noise occurred when the waveguide temperature was about 28°C, at which time the lamp temperature was 36°C. Evidently the temperature difference between the lamp bulb and the waveguide was about 8 degrees.

The resistance thermometer consisted of a bridge using WE106A 60-ohm resistors in three arms and a temperature-sensitive element in the fourth. The 106A resistors are relatively insensitive to temperature, the coefficient being 0.00017 per cent per degree C at 20°C, whereas the Driver Harris number 99 alloy used in the fourth arm had a coefficient of 0.006 per cent per degree C at 20°C. This was wound on a thin paper tube which could be slipped over the T5 lamp at the anode end, and placed as near the active waveguide as possible without disturbing the microwave field. The resistance of this winding was trimmed to balance the bridge at 20°C, and the upper limit of 60°C was set by the voltage applied across the bridge. Calibration of the bridge and the indicator, a 0 to 200  $\mu$ A 50-ohm meter, Fig. 5.

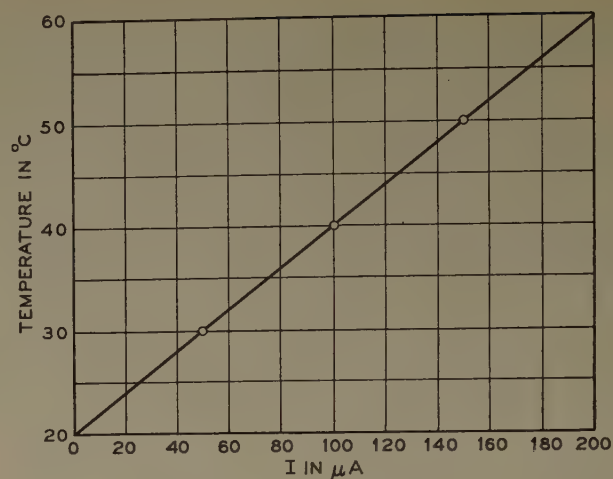


Fig. 5—Calibration of resistance thermometer.

Feeling that means were now available for measuring the lamp temperature quickly and accurately, ten lamps were measured in the high-frequency head. The excess noise versus the indicated lamp temperature for each of these is plotted in Fig. 6, which shows that each of the lamps exhibited evidence of the existence of an operating temperature where the coefficient was substantially zero, and that the spread among the lamps increased as the temperature increased, being  $\pm 0.15$  db at 26 degrees and  $\pm 0.45$  db at 45°C. The region near a lamp temperature of 32°C is thus interesting for

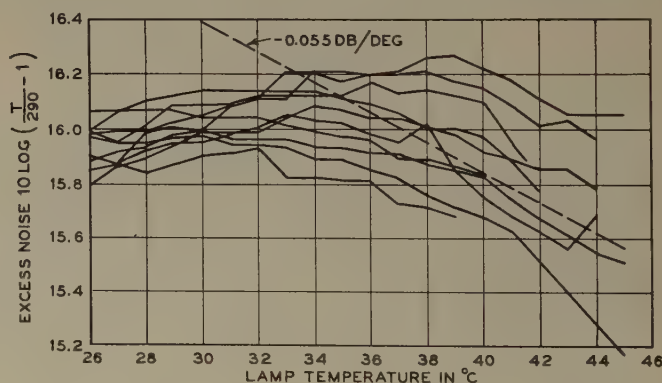


Fig. 6—Excess noise versus temperature for ten lamps.

two reasons; not only is the temperature coefficient negligible, but also the spread among different lamps is small. Unfortunately, this occurs at a temperature where the oscillation in the match may be bothersome, i.e., when the lamp temperature is 32°C (waveguide temperature around 24°C). According to the data of Fig. 2, the average SWR might be about 3.5 db, an intolerable value in some instances.

Thus it appears that the useful region should be confined to lamp temperatures above about 36°C, as indicated in Fig. 6. This corresponded to a waveguide temperature of about 28°C on Fig. 2, above which the SWR was less than a db. The temperature coefficient of  $-0.055$  db per degree C seems to fit fairly well most of the lamps tested, and the spread among the lamps

was about  $\pm 0.3$  db, as found previously. Accordingly, the temperature-measuring bridge was designed to include the region above  $36^\circ\text{C}$ .

A representative lamp was chosen from the lot and installed in a circuit. Its excess noise was measured over a temperature range of 29 to  $46^\circ\text{C}$ , and is given by the data of Fig. 7. A hand-calibrated scale was pasted on the face of the indicating meter of the resistance thermometer, thereby giving a direct-reading scale for excess noise power output in db.

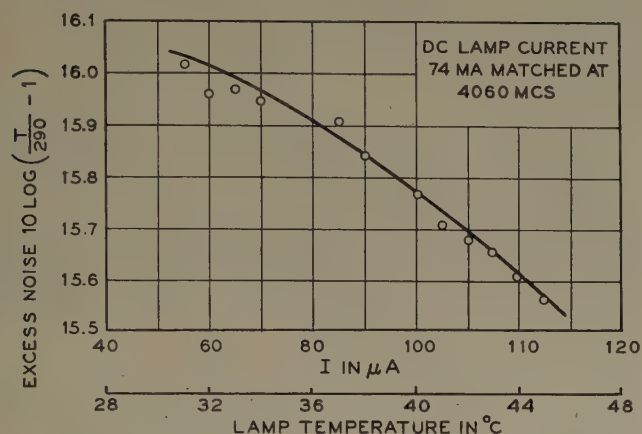


Fig. 7—Excess noise output versus temperature of the completed unit.

A conventional power supply mounting the resistance thermometer indicating meter, and a dc lamp current indicating meter, completed the unit. Switches were provided (SW 3, 4, 5, 6) to include any or all of a bank of fixed resistors in series with a fine trimming resistance  $R_8$ , so that the lamp current could be set at any value from 50 to 100 ma, the limits required to match the lamp to the waveguide over the range from 3,700 to 4,500 mc. It might be pointed out here that if the

lamp is matched at the mid-band, the SWR will not exceed 3 db over the band, and this is sufficiently good for many measurements. The resistance thermometer

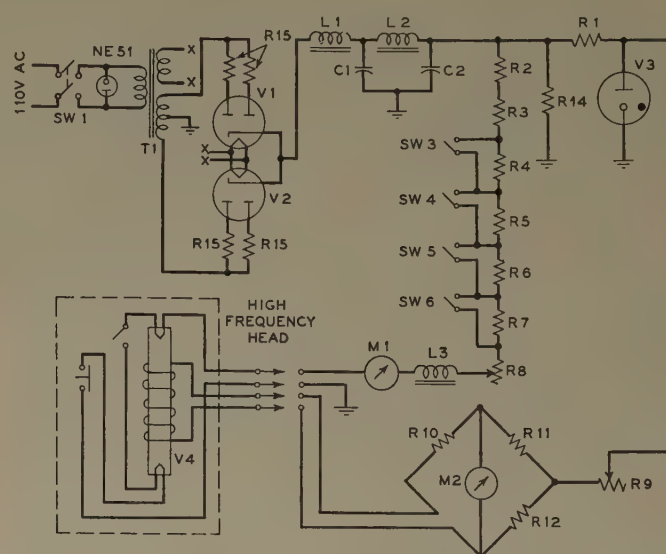


Fig. 8—Schematic of power supply and resistance thermometer

$C_1, C_2$ —Dual 40  $\mu\text{f}$  450-v electrolytic cond.  
 $R_1$ —Two 3K ohm 2 w resistors  
 $R_2, R_3$ —630 ohm 10 w resistors  
 $R_4, R_5, R_6$ —400 ohm 10 w resistors  
 $R_7$ —500 ohm 25 w potentiometer  
 $R_8$ —20K ohm potentiometer  
 $R_{10, 11, 12}$ —W.E. Co. 60-ohm type 106A resistors  
 $R_{13}$ —Driver Harris alloy #99 0.002" dia. wound on paper tube to approx. 60 ohms (see text).  
 $R_{14}$ —100K ohm 1 w resistor  
 $R_{15}$ —10 ohm 2 w resistors

$SW_{1, 2, 3, 4, 5, 6}$ —SPST toggle switches  
 $SW_7$ —Fluorescent push switch 1 NC contact momentary break, one NO momentary make contact.  
 $L_1, L_2$ —18 henry 100 ma chokes  
 $L_3$ —6 w fluorescent lamp ballast  
 $M_1$ —0–100 ma meter  
 $M_2$ —0–200 microampere 50 ohm meter  
 $PJ$ —Plug and jack connector  
 $V_1, V_2$ —6X4 vacuum tubes  
 $V_3$ —OB2 regulator tube  
 $V_4$ —6 w daylight fluorescent lamp  
 $T_1$ —Power transformer 700v CT 90 ma 5v 3a 6.3v 3.5a

bridge derives its power from the same supply, with a gas tube,  $V_3$ , acting as a regulator. Fig. 8 is a schematic diagram of the unit and a listing of the parts. Fig. 9 is a photograph of the completed unit.

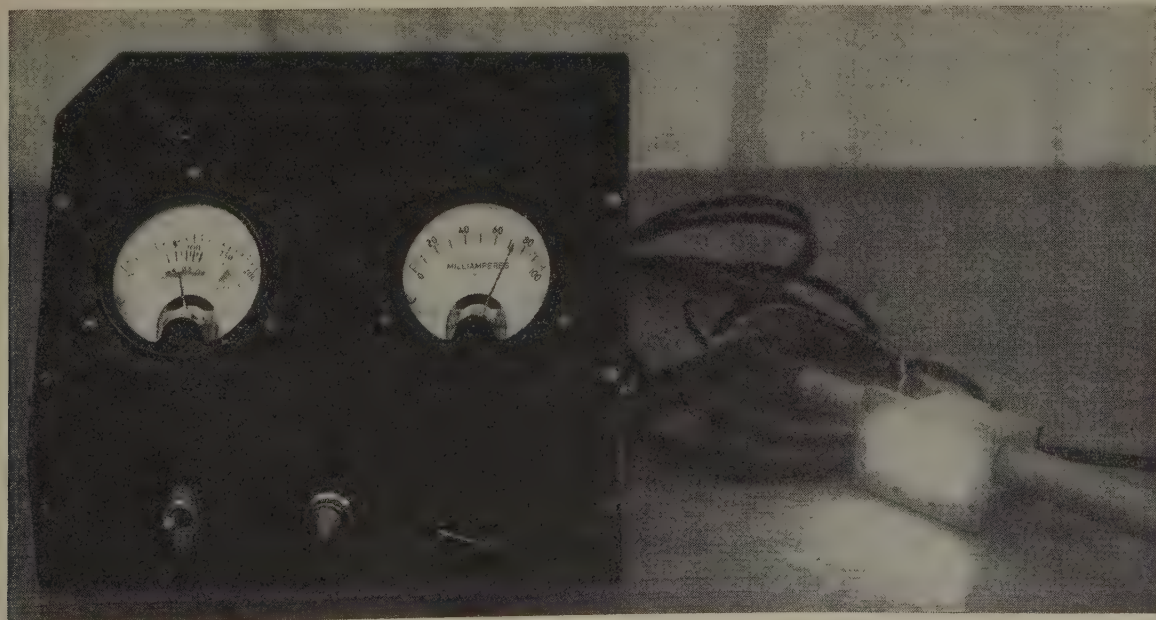


Fig. 9—Front view of completed unit with lamp lighted.

The completed direct-reading-microwave noise generator unit has been in use in the laboratory for some time, and has proven to be a useful tool for the measure-

ment of microwave noise figures on various equipments. The ease of operation and stability of this portable unit have been both time saving and gratifying.

## Discussion on

# "The Permittivity of Air at a Wavelength of 10 Centimeters"\*

W. ERIC PHILLIPS

**C. M. Crain:**<sup>1</sup> The article on permittivity of air and water vapor at 10 centimeters by Mr. Phillips, published in the July, 1950, PROCEEDINGS, was indeed interesting as it illustrates the world-wide interest in determining these important quantities.

There are a few points in the article, however, which I feel warrant comment. Mr. Phillips states that the published results of permittivity of dry air are confined to frequencies of the order of 50 megacycles. In the last few years at least two articles have been published on measured values of dielectric constants of dry air or its constituents in the neighborhood of 3.2 centimeters. Birnbaum at the Bureau of Standards in Washington, (1.) published measured values of dielectric constants of gases in this region. The Electrical Engineering Research Laboratory at The University of Texas (2.) has published measured values for the dielectric constants of both dry air and water vapor at 9,340 megacycles. Their measurements were obtained by heterodyning two stabilized Pound oscillators (3.).

Equation (3) in Mr. Phillips' article is apparently correct only if the radius of the resonant cavity remains constant. If I interpret Fig. 4 correctly, the outside wall of the resonant cavity was still subjected to atmospheric pressure when the cavity was evacuated. If the radius of the copper tubing is taken as 5.080000 centimeters when it is evacuated, then its radius will be, according to my calculations, neglecting end effects, 5.080068 centimeters when the pressure inside is one atmosphere. Then equation (3) for air should be

$$k_e = \frac{\frac{1}{\lambda_{ta}^2} + \left(\frac{r_{mn}}{2\pi a_a}\right)^2}{\frac{1}{\lambda_{tv}^2} + \left(\frac{r_{mn}}{2\pi a_v}\right)^2} = \frac{\frac{1}{\lambda_{ta}^2} + 0.005677137}{\frac{1}{\lambda_{tv}^2} + 0.005677344}$$

It is important to note that the constants in the numerator and denominator of the above equation are *different*. The difference between 0.005677344 in the

above equation, and 0.00567695, as used by Mr. Phillips, is of negligible consequence. If the above relation is used, for example, to calculate  $k_e$  for dry air in series 11a and 11b, page 789, one gets  $k_e = 1.000552$ , instead of 1.000573. Hence, it appears that the value for  $k_e$  of dry air at 0°C and 760 mm Hg, on page 790, should be 1.00058,  $\pm 0.00002$ . This value compares with 1.000577 in reference (1.) and 1.000572 in reference (2.).

There is apparently a misprint in equation (4). The value  $2\pi$  is obviously not correct. Using  $k_e$ , as above, equation (4) would read

$$k_e - 1 = \frac{210}{T} \left( P + \frac{48P_s}{T} H \right) 10^{-6}.$$

It is not clear how Mr. Phillips was able to quote a value for  $k_e$  for water vapor at 100° C on the basis of his measurements at 23° C and the Clausius-Mosotti relation. Water vapor is a polar molecule, and hence has a dielectric constant which is approximately related to temperature as follows:

$$k_e - 1 = \frac{A}{T} + \frac{B}{T^2},$$

where  $A$  and  $B$  are constants which may be determined by measuring  $k_e$  at two different temperatures. It is possible, however, using the Debye equation (4), to calculate the value of  $k_e$  at 100° C from the measured value at 23° C if one assumes either values quoted by other observers for the dipole moment of the water molecule, or uses a value from the literature for  $k_e$  of water vapor at frequencies in the infrared region of the frequency spectrum. In the infrared region, the dipole moment does not contribute to the dielectric constant; hence,  $k_e - 1$  can be taken as simply  $A/T$ .

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\* W. E. Phillips, "The permittivity of air at a wavelength of 10 centimeters," *Proc. I.R.E.*, vol. 38, pp. 786-790; July, 1950.

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# A General-Purpose Electronic Wattmeter\*

DON E. GARRETT†, ASSOCIATE, IRE AND FRANK G. COLE†, ASSOCIATE, IRE

**Summary**—A direct reading wattmeter is described which will read either positive or negative peak or average power of complex voltage and current waveforms containing components in the frequency range from dc to 71 kc. The instrument will measure up to 50 watts, covered in three ranges with an accuracy of 3 per cent. The scale may be extended by suitable resistance changes. The voltage and current inputs are mutually dc isolated to allow measurement of the current at any point between the ground and the voltage source.

Multiplication of the current and voltage is accomplished by modulating a 10-mc carrier with the current, and then modulating the resultant with the voltage in a cascade of two suppressed-carrier modulators. The instantaneous product is recovered in a phase-sensitive demodulator, and then passed through an integrating network for average power, or through a peak detector for peak power.

The wattmeter was designed with particular reference to the measurement of the plate dissipation in television horizontal output tubes. It was designed, nevertheless, to be a general-purpose instrument capable of accurately measuring power in any type of circuit where the voltage and current involved can be measured.

## INTRODUCTION

THE MEASUREMENT of the plate dissipation of the horizontal-sweep output tube in television receivers has, in the past, been a nebulous problem. Economics require receiver manufacturers to employ small tubes operating near maximum capacity. Consequently, it is necessary to determine the actual plate dissipation of power-amplifier tubes in some manner to avoid epidemics of tube failure. Also it is desirable to have the method compatible with design procedures where the effect of a circuit change or adjustment can be noted immediately. The power measurement is made difficult by the complexity of plate voltage and current waveforms. It is further complicated by the voltage crest of four kv or more during the retrace period, while the average voltage during current conduction is perhaps only a hundred volts.

Many methods have been devised to measure the plate dissipation of the horizontal output tube. These can be divided roughly into tube-envelope temperature measurements and voltage-and-current measurements.

Power measurements made by the temperature methods consist of noting the bulb temperature during the actual operating conditions and then reproducing the same temperature later with a dc plate voltage and current. Plate dissipation is then given by the product of these dc values. Screen and filament dissipation, of course, must be held constant.

A relatively crude method that has been used consists of painting stripes of wax, each with different melting points, on the bulb and then noting which of these melt during operation. Other methods have in-

cluded a resistance wire bridge, a thermocouple, and an oil-bath calorimeter. Of these, the oil-bath calorimeter is perhaps the most accurate but the most inconvenient. Temperature methods are not popular, however, because of the time required to make temperature measurements.

Heretofore, power measurements made by the voltage and current methods have been indirect and less accurate than the temperature methods because of the complex nature of the waveforms involved. Independent readings of average plate voltage and current cannot be employed to yield the average plate dissipation because true average power is defined as the time average of the instantaneous product of current and voltage. It is possible to form the product graphically from oscilloscope traces of the voltage and current, but this procedure is slow and not very accurate because the high surge voltage during retrace obscures the voltage during actual plate-current conduction.

An indirect method utilizing voltage and current measurements has been devised by C. E. Torsch<sup>1</sup> and had been used by the Receiver Department of the General Electric Company in the design of horizontal output stages. By this method, a pessimistic though approximate average plate voltage during conduction is found by making certain measurements at the secondary of the output transformer. Admittedly, the method is not theoretically accurate, but it does give a slightly conservative comparative dissipation figure in a relatively short time.

This review indicates that direct-reading accurate wattmeter would greatly facilitate power measurements in television circuits. The requirements for the instrument are

- (a) complex waveforms must be handled,
- (b) dc components of the inputs must be preserved,
- (c) separate dc reference levels for the current and voltage inputs must be allowed so that the current can be measured in the plate circuit of tubes to avoid the screen current, and
- (d) frequencies from dc to several hundred kc should be passed so that power contained in the harmonics may be measured.

None of the electronic wattmeters discussed in the literature<sup>2</sup> satisfy all the requirements simultaneously.

<sup>1</sup> C. E. Torsch, "A universal-application cathode ray sweep transformer with ceramic iron core," *Tele-Tech*, vol. 9; January 1950.

<sup>2</sup> J. R. Pierce, "A proposed wattmeter using multielectrode tubes," *Proc. I.R.E.*, p. 1743; October, 1930. G. Dexter, "Universal af-rf wattmeter," *Radio News*, p. 66; May, 1948. L. R. Malling, "Electronic wattmeter," *Electronics*, p. 133; November, 1945. E. Mittelmany, "High-frequency wattmeter," *Electronics*, p. 324; March, 1945. R. Bauch, "Hot-wire wattmeter," *Elektrotech. Z.*, p. 530; July 9, 1903. G. H. Brown, J. Epstein, and D. W. Peterson, "Direct-reading wattmeters for use at radio frequencies," *Proc. I.R.E.*, p. 403; August, 1943. H. M. Turner and F. T. McNamara,

\* Decimal classification: R245.3. Original manuscript received by the Institute, February 8, 1951; revised manuscript received, August 6, 1951.

† Receiver Department, General Electric Company, Electronics Park, Syracuse, New York.



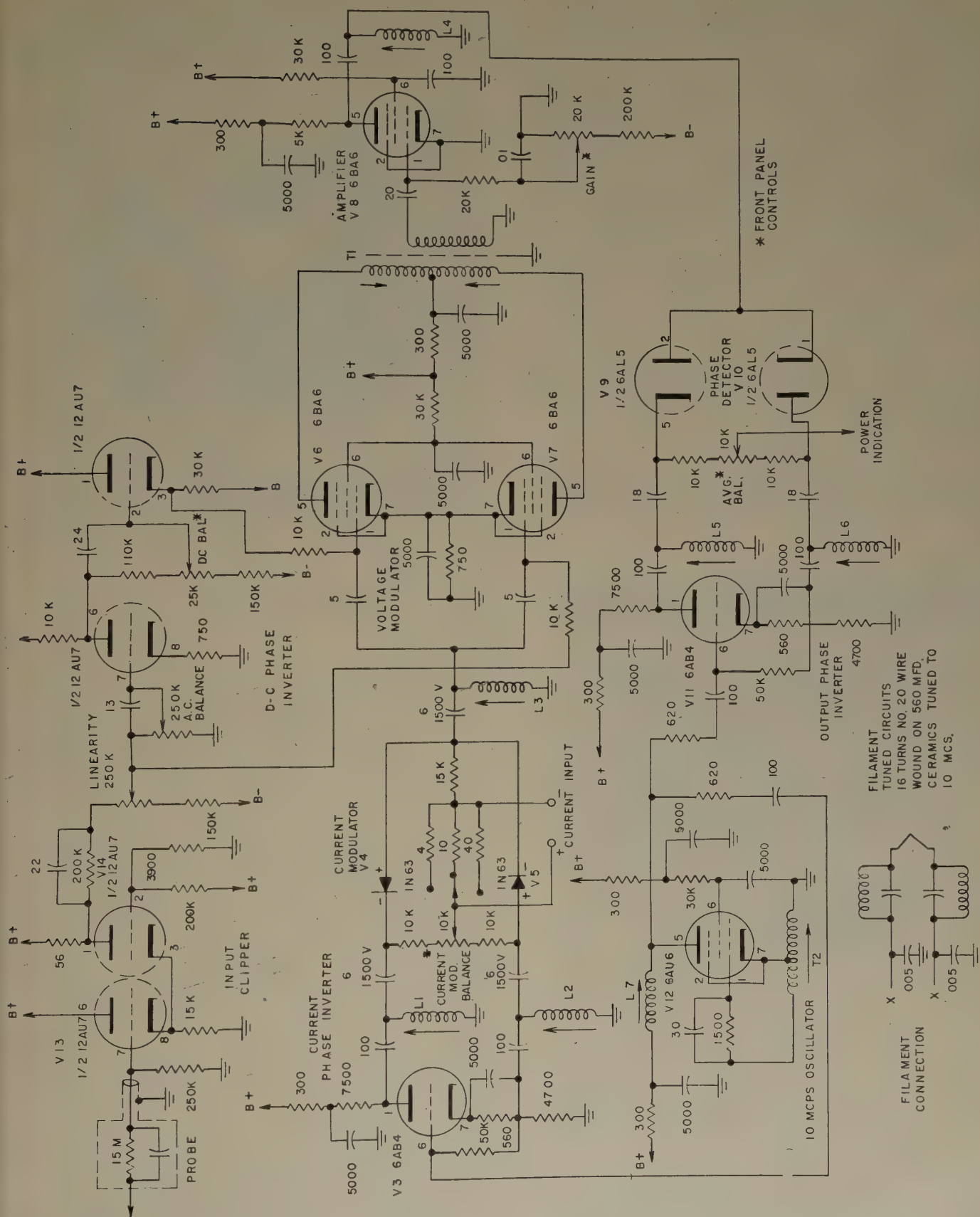


Fig. 2—Circuit schematic of electronic wattmeter.

meter described, three ranges are provided by switching in either a 4-ohm, 10-ohm, or 40-ohm resistor.

### Voltage Modulator

The next problem is to remodulate the above signal with the voltage input. The use of a second diode modulator is precluded since the output amplitude of this type of modulator is dependent upon the smaller input voltage. However, a satisfactory circuit is obtained with two variable-gain tubes connected so that their plate current subtracts and their grid voltages are, respectively,

$$e_{g1} = i \cos wt + e \quad (3)$$

and

$$e_{g2} = i \cos wt - e, \quad (4)$$

where  $e$  is the voltage waveform.<sup>4</sup> The plate current of these tubes, over a small range, may be expressed by the power series

$$ip = a + be_g + ce_g^2 + de_g^3 + \dots \quad (5)$$

Substituting the grid voltages of (3) and (4) into the power series of (5) and then subtracting, one obtains

$$i_{p1} - i_{p2} = 2be + 2de^3 + 4cie \cos wt + 2di^2e \cos^2 wt \quad (6)$$

for the first four terms of the power series. The subsequent tuned circuits remove all components except the carrier-frequency term, leaving

$$i_{p1} - i_{p2} = 4cie \cos wt. \quad (7)$$

The constants  $a$ ,  $b$ ,  $c$ , and  $d$  may be matched over the operating range by adjustment of the relative dc bias and the ac grid drive on the variable-gain pentodes, V-6 and V-7, Fig. 2. It was originally thought that the voltage-modulator pentodes would have to be carefully matched. Under actual operation, several randomly selected tubes operated as linearly as matched tubes when the individual quiescent bias was properly adjusted.

### Voltage-Input Circuit

Push-pull voltage inputs are required by the voltages modulator. A direct-coupled phase inverter is used to provide the push-pull voltages since the instrument must preserve the dc component. The voltage is sampled through a capacitively compensated high-impedance probe having an input impedance of 15 megohms and 1.5  $\mu$ mf. Other probes having a different impedance in conjunction with various terminating circuits can extend the voltage range of the wattmeter to any desired value.

For accurate measurement of the plate dissipation of television horizontal output tubes, the high surge during retrace is removed by a clipper. Removal of the surge allows increased sensitivity over the active por-

tion of the cycle. The validity of surge voltage clipping is dependent upon no plate-current flow during the high-voltage peak. To eliminate measurement errors here, the grid drive on the horizontal output tube must cut off the plate current instantaneously. If the cut-off voltage is sluggish or of insufficient amplitude, then certainly some current will flow during the plate voltage pulse, contributing a small error to the wattage reading.

### Amplifier

The voltage modulator output is passed through an adjustable-gain amplifier, V-8 Fig. 2, so that the wattage indication may be varied for calibration purposes, and to compensate for tube aging and drift. Although little error has been found to be associated with this variable-mu tube amplifier, let us determine the spurious modulation products generated. The first four terms of the power series of (5) indicate an output voltage from  $V_8$ , when filtered by the plate circuit, of

$$e = K[bie + 3/4 dk^2(ie)^3] \cos wt. \quad (8)$$

The spurious term introduced by intermodulation is  $3/4 dk^2(ie)^3$ , where  $d$  is the third-order constant defined by (5). The third-order curvature of the tubes characteristic is very small compared to the linear term, and, in addition, the signal input to this stage is only a few mv. Consequently, the error introduced should not be the limiting feature of the wattmeter.

### Demodulator

The remaining problem is to demodulate or to recover the carrier modulation defined by (7). The demodulator must be more than an amplitude detector since the phase of the carrier contains the power polarity information. Therefore, the demodulator must be both amplitude and phase sensitive. This characteristic is exhibited by the common diode-type phase detector.<sup>5</sup> The modification of the conventional phase detector used allows ground reference for both the carrier and signal inputs. The circuit configuration is exactly the same as the current modulator

The diode demodulator can best be explained by examining the voltages involved. The diodes, V-9 and V-10, Fig. 3, in combination with their associated RC circuits, comprise separate peak detectors. Consequently, the capacitors will charge up to the peak voltage across V-9 and V-10, respectively. Let the peak amplitude of the push-pull carrier inputs be  $E$ , and the peak amplitude of the modulated input be proportional to the instantaneous modulation ( $ie$ ). The latter stipulation will be true if the modulating frequency is much lower than the carrier frequency. The peak voltage across V-9 and V-10 will be  $(E+ie)$  and  $(E-ie)$ , respectively. The voltage at the output terminal will be one-half the difference of the voltage on each charg-

<sup>4</sup> W. L. Everitt, "Communication Engineering," McGraw-Hill Book Co., New York, N. Y., 2nd ed., p. 390; 1937.

<sup>5</sup> W. L. Emery, "Ultra-High-Frequency Radio Engineering," Macmillan Co., New York, N. Y., p. 41; 1944.

ing capacitor, giving a demodulated output of the instantaneous product (*ie*). With no input from the amplifier V-8, the voltage at the output terminal should be zero. A balance adjustment is provided so that the output will be zero in this circumstance.

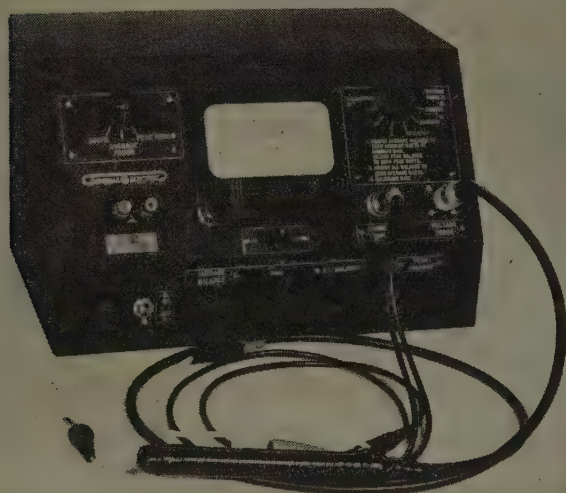


Fig. 3—Direct-reading electronic wattmeter for complex waveforms, front view.

#### Output Filters

Three circuits are provided at the output of the phase detector. One is simply a resistance termination through which the power waveform may be observed on an oscilloscope. The second is an integrating circuit, or a low-pass filter, which averages the power over the cycle, thus giving the average power. The third is a peak detector which measures the peak power during cycle. The meter at the output is calibrated directly in watts.

#### Calibration

Calibration of the meter is accomplished by applying a known voltage to the current and voltage terminals. The resulting power indication may be calculated and the gain control adjusted for this reading on the meter at the output. In the instrument described, a fixed voltage is applied internally and the gain control is adjusted until the wattage indication coincides with a mark on the meter scale.

#### Stability

It is interesting to note that the stability of the carrier-frequency oscillator is not important providing the instrument is calibrated prior to using. Should the oscillator drift, the tuned circuit response results in reduced amplitude and introduces a phase shift in the carrier. The reduced amplitude may be directly compensated for by a suitable gain adjustment. The effects of the phase shift are not as obvious. However, since the output stage is a phase detector, the power indication will vary as the cosine of the phase-shift angle. This

again merely produces a reduced sensitivity, and may be compensated for by a suitable gain adjustment. It was necessary to load down the tuned circuits so that the high-frequency components of the voltage and current inputs would not be attenuated; therefore, the tuned-circuit  $Q$  is relatively low. Consequently, a frequency shift in the oscillator will have only a small effect.

Stability is also affected by power-supply variations since the voltage input-circuit is direct coupled. To avoid as much instability as possible from this source, a well regulated power supply is required.

#### Shielding and Layout

Perhaps the most important consideration in the construction of the wattmeter is the circuit layout. When either the voltage or current input is zero, the wattage indication must be zero for all values of the nonzero input. To realize this requirement, either absolutely no feed through of the carrier can be tolerated, or the feed through must be equal but out of phase. For best results an attempt was made to both minimize and balance all cross talk. This was accomplished by symmetrical layout and extensive shielding. The shielding is apparent in the bottom view of the chassis, Fig. 4.

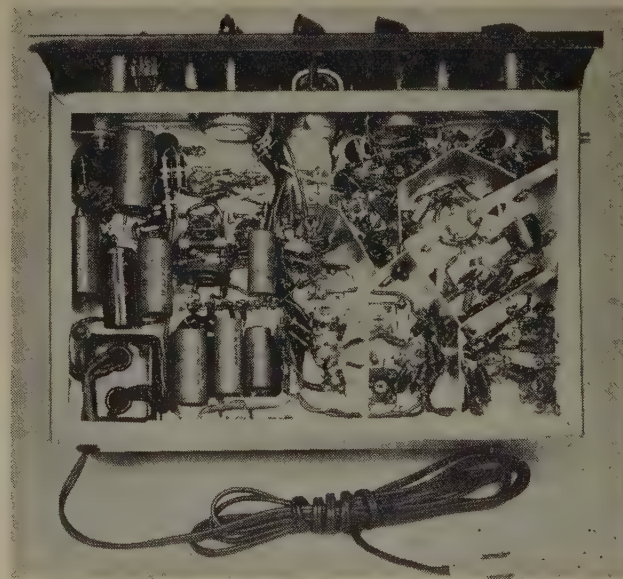


Fig. 4—Bottom view of electronic wattmeter.

#### PERFORMANCE

The salient performance characteristics of the wattmeter that are of interest are the calibration, error, frequency response, and stability. Of primary interest, of course, is actual measurements on television sets.

#### DC Calibration

The dc calibration curves are shown on Fig. 5 (see following page) for various values of current and voltage input. The indication error may be seen to be within

3 per cent of full scale for all inputs within the range of the instrument. When the polarity of either input is reversed, the reading is duplicated in the negative direction.

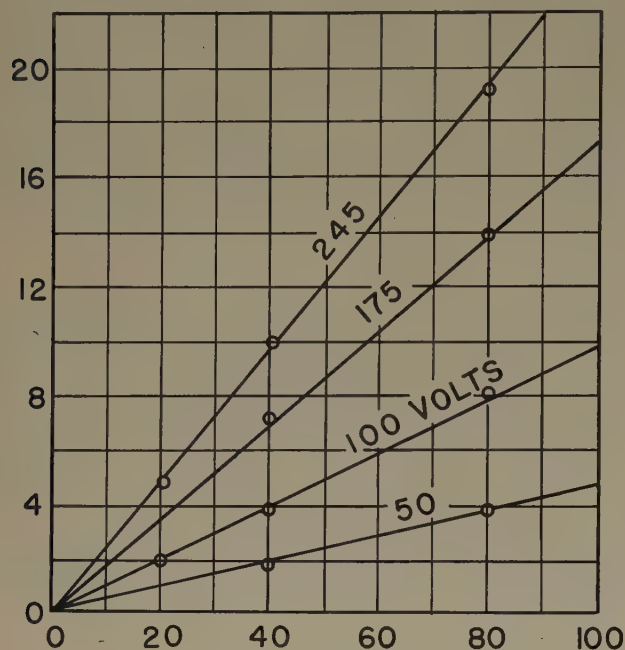


Fig. 5—DC performance.

A desirable feature of this wattmeter is that the unit operates at the same level on all ranges since the range selector is at the input. The maximum voltage that can be handled without overloading the voltage input circuit is 245 volts. The maximum current inputs are 100 ma, 400 ma, and 1 amp for the 5-, 20-, and 50-watt ranges, respectively. Perhaps an improvement would be to provide external terminals for the current sampling resistor so that any combination of current and voltage could be handled.

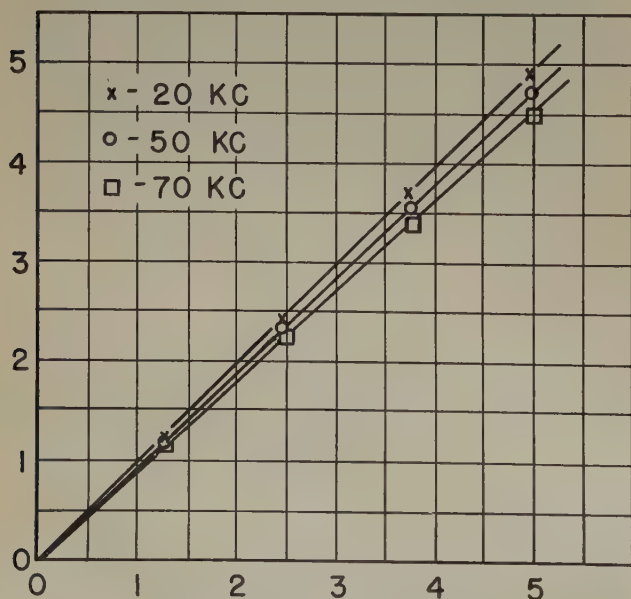


Fig. 6—Square-wave inputs.

### Square-Wave Test

Fig. 6 shows the power indication resulting from a negative-going, square-wave voltage input and a dc current input. The calculated power, as shown in the figure, agrees well with that measured over the applicable frequency range of the wattmeter. This test supplements the dc calibration curves and, in addition, demonstrates the ability of the instrument to handle complex waveforms.

### Power-Factor Test

With a 60-cps source, the power consumed by an  $RC$  network was measured with both this wattmeter and a dynamometer-type wattmeter. For two values of voltage, the power factor was varied from unity to 0.014, as shown in Fig. 7. The resulting indication agreed very closely, as may be seen from the curve. It was necessary, of course, to use a high-quality dynamometer wattmeter as the standard.

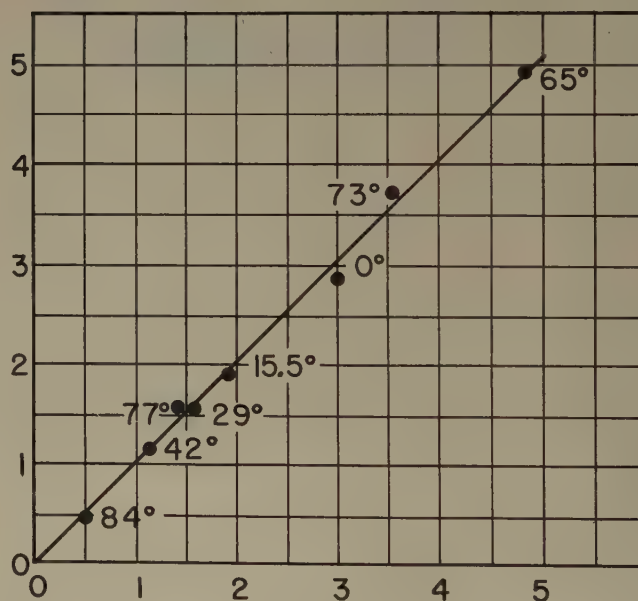


Fig. 7—Power-factor test.

### Frequency Responses

The frequency response curves for the wattmeter are shown in Fig. 8. The response was measured with dc current and ac voltage inputs. Since the power was zero, the power waveform was observed on an oscilloscope and the amplitude as a function of frequency was noted. The 0.707 point may be seen to fall at 71 kc. Even though this is below the goal set, it is thought to be satisfactory since the lower-frequency power predominates in the horizontal output tube of television sets. This is true because the plate voltage during current conduction remains practically constant, with the higher-frequency components associated with rise time and high-frequency response contributing very little.

Actually, there are some high-frequency harmonics in the voltage waveform, and these must be passed if a true power reading is to be obtained. Since the higher frequencies are not passed, it is expected that the wattage indication, in television applications, will be slightly low.

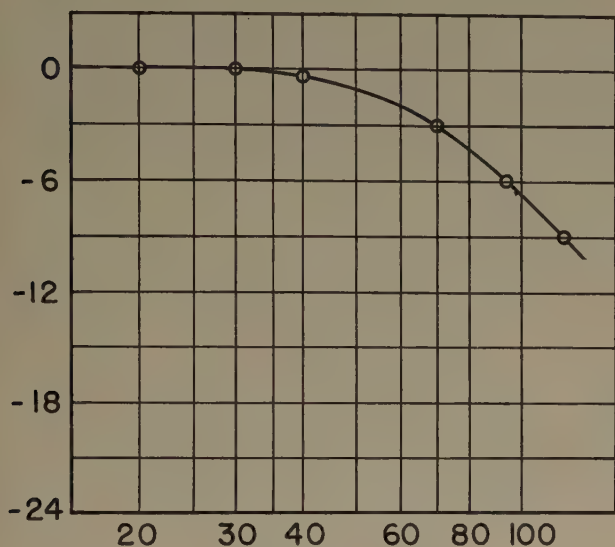


Fig. 8—Frequency response.

### Television-Set Testing

The wattmeter has performed satisfactorily with regard to television-set measurements. A comparative check made on a General Electric 16T1 set using the wattmeter, the temperature method, and the approximate method of reference one gave 8.8 watts, 8.92 watts, and 10.5 watts, respectively, of horizontal output-tube plate dissipation. The wattmeter reads slightly less than the temperature method, which is assumed to be the most nearly correct, as would be expected since the wattmeter attenuates some of the higher-frequency components. Actually, the two readings are not significantly different since the wattmeter allowable error is 3 per cent. The approximate method of reference one results in a somewhat larger reading, as may be predicted from an analysis of the method.

A calibrated source simulating the voltage and current of a television horizontal output stage is used to check the probe and wattmeter calibration for pulsed inputs. The calibrator, therefore, insures accurate readings for a television signal.

### Drift

There is a gradual drift in the zero setting and calibration during the first hour or so of operation. After a suitable warm-up period the unit stabilizes, and recalibration is necessary again only after a prolonged period of use. Sufficient controls for drift adjustment are brought out on the front panel. These include the

voltage modulator dc balance, phase-detector balance, and gain control. A calibration switch is incorporated which terminates the voltage and current inputs so that it is not necessary to disconnect the test leads from the unit being measured when the wattmeter is recalibrated. In addition, the switch applies a calibration voltage to each modulator for zero adjustment, and then applies the voltage to both inputs for gain adjustment.

### CONCLUSIONS

Let us examine the performance of the electronic wattmeter to see if the initial requirements have been met. The performance stipulations for the instrument were: Complex waveforms must be handled including the dc component; an arbitrary dc voltage must be allowed to exist between the voltage and current inputs; and frequencies from dc to several hundred kc should be passed.

Complex waveform performance was established by square-wave tests, power-factor tests, and actual measurement of the television horizontal output-tube plate dissipation. By square-wave tests and by the dc performance curves, dc operation was also established. The very nature of the circuitry of the wattmeter is sufficient to indicate that a dc voltage may exist between the voltage and current inputs. Even so, while checking the instrument calibration, the current-terminal potential was varied over wide limits with no effect whatsoever on the wattage indication.

The frequency response is below that desired, being only 71 kc. This response is adequate for TV applications, as has been explained. There is no basic reason, however, why this figure cannot be revised upwards to at least 1 mc if a particular application should require this response.

The accuracy is within 3 per cent, which is acceptable in view of the purpose of the wattmeter of providing an instantaneous wattage reading for developmental work on television sets.

Although the unit has been designed to measure television horizontal output tube losses, versatility has been maintained. The wattage range may be varied to suit any individual measurement problem by suitable resistance changes. The wattmeter can be used equally well for measuring miscellaneous circuit losses, such as in the high-voltage transformer, yoke, and vertical circuits. Its peak-reading feature makes it valuable for measuring peak power in pulsed circuits, such as those encountered in radar. In short, it can be used to measure power where any sort of complex waveforms are encountered.

### ACKNOWLEDGMENT

The authors wish to acknowledge their indebtedness to Charles E. Torsch of the General Electric Company for his constructive criticisms and for his continued interest, which made this development possible.

# Distortion of a Frequency-Modulated Signal by Small Loss and Phase Variations\*

F. ASSADOURIAN†

**Summary**—General formulas are developed for harmonic and total distortion in the frequency of the outputs of linear transmission systems with pure frequency-modulated inputs and with amplitude and phase characteristics involving wiggles that can be represented approximately by single sinusoidal functions of small amplitude. The amplitude wiggles represent departure from flatness, and the phase wiggles departure from linearity. This first-order analysis yields a result for total distortion  $D$ , which varies linearly with the amplitude of either wiggle if the amplitude of the other is made zero. It will be seen that  $D$  is periodic in the frequencies of the wiggles and in the audio frequency  $p$  and carrier frequency  $\omega_c$  of the frequency-modulated input. Of course,  $D$  is also a function of its index of modulation  $m$ . The formulas for  $D$  can be applied to amplifiers, filters, and the like in a communication system that satisfies the above assumptions.

General distortion formulas are applied to waveguides loaded by pure resistances. Among other things, the so-called "long-line" effect in distortion is discussed. Graphs show the dependence of distortion on various parameters.

## I. SINUSOIDAL REPRESENTATION OF AMPLITUDE AND PHASE WIGGLES

THE ANALYSIS starts with the general linear four-terminal network indicated in Fig. 1. If  $E_1$  is a constant-voltage generator of frequency  $\omega$ , then the solution for  $E_2$  in terms of  $E_1$  has the form

$$E_2 = G(j\omega)E_1 = A(\omega)e^{-i\phi(\omega)}E_1, \quad (1)$$

where  $G(j\omega)$  is dimensionless and is written in polar form. As is well known, nonflatness of  $A(\omega)$  and nonlinearity of  $\phi(\omega)$  will generally produce harmonic distortion in the frequency of  $E_2$  if  $E_1$  is a pure frequency-modulated wave.



Fig. 1—Linear four-terminal network.

It will be assumed now that  $A(\omega)$  and  $\phi(\omega)$  have the forms indicated in (2).

$$\left. \begin{aligned} A(\omega) &= 1 + \mathcal{E}_1 \cos 2b(\omega - \omega_1), \\ \phi(\omega) &= c(\omega - \omega_0) + \mathcal{E}_2 \sin 2d(\omega - \omega_2). \end{aligned} \right\} \quad (2)$$

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The amplitude and phase characteristics described by (2) are illustrated in Fig. 2. It is assumed that  $\mathcal{E}_1$  and  $\mathcal{E}_2$  are small and that higher powers of  $\mathcal{E}_1$  and  $\mathcal{E}_2$  can be disregarded in all steps of the subsequent analysis. It should be noted that (2) applies not only to waveguides, but to other types of networks as well.

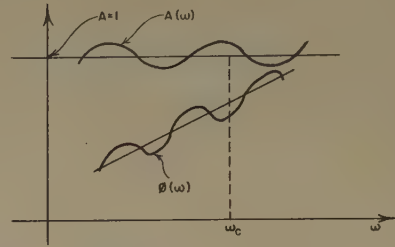


Fig. 2—Amplitude and phase characteristics with sinusoidal variation.

## II. DERIVATION AND DISCUSSION OF DISTORTION FORMULAS

To obtain the distortion in the frequency of  $E_2$  (see Fig. 1) when  $E_1$  is a pure frequency-modulated input, the sideband analysis is followed.  $E_1$  is defined by

$$\begin{aligned} E_1 &= E_0 \sin(\omega_c t + m \sin pt) \\ &= E_0 \sum_{k=-\infty}^{\infty} J_k(m) \sin(\omega_c + kp)t, \end{aligned} \quad (3)$$

where  $E_0$  is constant,  $\omega_c$  is the carrier frequency,  $p$  is the modulating frequency, and  $m$  is the index of modulation. The instantaneous frequency  $\Omega$  in (3) is the derivative of the phase and has the form

$$\Omega = \omega_c + mp \cos pt. \quad (4)$$

Note that  $mp$  represents the maximum deviation of the modulating from the carrier frequency.

If each term of the input  $E_1$  is altered suitably with the use of  $A(\omega)$  and  $\phi(\omega)$  according to the steady-state theory, the output  $E_2$  is given by

$$\left. \begin{aligned} \frac{E_2}{E_0} &= \sum_{k=-\infty}^{\infty} [1 + \mathcal{E}_1 \cos 2b(\omega_c' + kp)] \\ &\quad J_k(m) \sin[(\omega_c + kp)(t-c) - \mathcal{E}_2 \sin 2d(\omega_c'' + kp) + \omega_0 c], \\ \omega_c' &= \omega_c - \omega_1, \quad \omega_c'' = \omega_c - \omega_2. \end{aligned} \right\} \quad (5)$$

As expected, the linear term  $c\omega$  in the expression for  $\phi$  leads to a delay, but does not produce distortion. It is convenient to replace  $t-c$  by  $\tau$ .

If (5) is expanded and higher powers of  $\mathcal{E}_1$  and  $\mathcal{E}_2$  are neglected, the result is

$$E_2/E_0 = (A^2 + B^2)^{1/2} \sin(\omega_c \tau + \omega_0 c + \psi), \quad \tau = t - c, \quad (6)$$

where  $A$ ,  $B$ , and  $\Psi$  are defined by

$$\left. \begin{aligned} A &= \sum_{-\infty}^{\infty} J_k(m) [\cos k p \tau + \mathcal{E}_1 \cos 2b(\omega_c' + kp) \cos k p \tau \\ &\quad + \mathcal{E}_2 \sin 2d(\omega_c'' + kp) \sin k p \tau] \\ B &= \sum_{-\infty}^{\infty} J_k(m) [\sin k p \tau + \mathcal{E}_1 \cos 2b(\omega_c' + kp) \sin k p \tau \\ &\quad - \mathcal{E}_2 \sin 2d(\omega_c'' + kp) \cos k p \tau] \end{aligned} \right\} \quad (7)$$

$\tan \Psi = B/A$ .

Equation (6) indicates that the output voltage  $E_2$  is generally no longer a pure frequency-modulated wave. It now has a new instantaneous frequency

$$\Omega = \omega_c + d\psi/d\tau. \quad (8)$$

It turns out that both  $\psi$  and  $d\psi/d\tau$  are periodic functions of time with fundamental period  $2\pi/p$  and can be expanded in Fourier series;  $d\psi/d\tau$  can be expressed in the form

$$\left. \begin{aligned} \frac{1}{p} \frac{d\psi}{d\tau} &= m \cos p\tau + \mathcal{E}_1 \sum_{k=-\infty}^{\infty} k J_k(2m \sin pb) \cos \\ &\quad [k(pb + \pi/2) + 2b\omega_c'] \cos k p \tau + \mathcal{E}_2 \sum_{k=-\infty}^{\infty} k J_k \\ &\quad (2m \sin pd) \sin [k(pd + \pi/2) + 2d\omega_c''] \sin k p \tau. \end{aligned} \right\} \quad (9)$$

The last result is basic in distortion calculations. Higher-harmonic terms beyond the first represent distortion in the original modulation. It should be recalled that (9) is a first-order result that is applicable to any network for which  $A(\omega)$  and  $\phi(\omega)$  have the forms indicated in (2) and Fig. 2. Even if  $A(\omega)$  and  $\phi(\omega)$  are approximately given by (2) for a finite frequency range that includes the essential band of  $E_1$ , (9) may still be used.

For distortion calculations, (9) may be written in the form

$$\left. \begin{aligned} \frac{1}{p} \frac{d\psi}{d\tau} &= m \cos \theta + \sum_{k=1}^{\infty} k (\mathcal{E}_1 A_k \cos k\theta \\ &\quad + \mathcal{E}_2 B_k \sin k\theta), \quad \theta = p\tau, \\ A_k &= J_k(u) [\cos (kb_1 + b_2) \\ &\quad + (-1)^{k+1} \cos (-kb_1 + b_2)], \\ B_k &= J_k(v) [\sin (kd_1 + d_2) \\ &\quad + (-1)^k \sin (-kd_1 + d_2)], \\ u &= 2m \sin pb, \quad v = 2m \sin pd, \\ b_1 &= pb + (\pi/2), \quad b_2 = 2b(\omega_c - \omega_1), \\ d_1 &= pd + (\pi/2), \quad d_2 = 2d(\omega_c - \omega_2). \end{aligned} \right\} \quad (10)$$

One can put (10) in the final form

$$\begin{aligned} \frac{1}{p} \frac{d\psi}{d\tau} &= m \cos \theta + \sum_2^{\infty} k C_k \sin (k\theta + \phi_k), \\ C_k^2 &= \mathcal{E}_1^2 A_k^2 + \mathcal{E}_2^2 B_k^2, \end{aligned} \quad (11)$$

where the first term of the sum in (10) has been omitted because it leads to higher-order terms in the distortion.

The definitions of distortion used in this report are given by

$$\begin{aligned} k\text{th-harmonic distortion} &= D_k = k C_k / m, \\ \text{total distortion } D &= \left( \sum_2^{\infty} k^2 C_k^2 \right)^{1/2} / m. \end{aligned} \quad (12)$$

An expression for harmonic distortion  $D_k$  can be obtained from (10) and (11).

If  $D_A$  is the total distortion due to amplitude wiggles alone ( $\mathcal{E}_2=0$ ) and  $D_\phi$  is the total distortion due to phase wiggles alone ( $\mathcal{E}_1=0$ ), then one can write

$$D^2 = D_A^2 + D_\phi^2, \quad D_k^2 = D_{kA}^2 + D_{k\phi}^2. \quad (13)$$

It is evident from (13) and previous equations that, to a first order, there is no combination of amplitude and phase wiggles that will improve the distortion, harmonic or total, due to either alone.

The summation in (12) leads to

$$\left. \begin{aligned} 4m^2 \frac{D_A^2}{\mathcal{E}_1^2} &= 4m^2 \sin^2 pb \\ &\quad + 2m \sin pb \cos 4b(\omega_c - \omega_1) \left[ J_1(4m \sin pb) \right. \\ &\quad \left. + 4m J_0(2m \sin 2pb) \sin^2 pb - \frac{J_1(2m \sin 2pb)}{\cos pb} \right] \\ &\quad - 8m^2 J_0(4m \sin^2 pb) \sin^2 pb \cos^2 pb \\ &\quad + 2m J_1(4m \sin^2 pb) \\ &\quad - 16 J_1^2(2m \sin pb) \sin^2 pb \cos^2 2b(\omega_c - \omega_1), \\ 4m^2 \frac{D_\phi^2}{\mathcal{E}_2^2} &= 4m^2 \sin^2 pd \\ &\quad + 2m \sin pd \cos 4d(\omega_c - \omega_2) \left[ J_1(4m \sin pd) \right. \\ &\quad \left. - 4m J_0(2m \sin 2pd) \sin^2 pd + \frac{J_1(2m \sin 2pd)}{\cos pd} \right] \\ &\quad + 8m^2 J_0(4m \sin^2 pd) \sin^2 pd \cos^2 pd \\ &\quad - 2m J_1(4m \sin^2 pd) \\ &\quad - 16 J_1^2(2m \sin pd) \cos^2 pd \cos^2 2d(\omega_c - \omega_2). \end{aligned} \right\} \quad (14)$$

It can be seen from (14) that  $D_A$  has period  $\pi$  in  $pb$  and  $2b(\omega_c - \omega_1)$ , and that  $D_\phi$  has period  $\pi$  in  $pd$  and  $2d(\omega_c - \omega_2)$ . Note that  $p = 2\pi f_a$ , where  $f_a$  is audio frequency, and  $b$  or  $d$  is related to the number of amplitude or phase wiggles per unit frequency (see Fig. 2). Fig. 2 can be used to give a crude partial check on the results in (10) and (14), if it is recalled that the amplitude and phase wiggles have period  $\pi$  in  $pb$  and  $pd$ , respectively. For example, if  $pb = \pi$ , then  $\omega_c$  and all the sidebands of

the frequency-modulated input fall on a flat line as far as amplitude is concerned. Hence, there should be no distortion  $D_A$  due to amplitude alone. From (14), it is seen that  $D_A=0$  for  $pb=\pi$ . If  $pd=\pi$ , then  $\omega_c$  and the sidebands of the frequency-modulated input fall along a line through the phase characteristic, and  $D_\phi$  should be zero. From (14) it is seen that  $D_\phi=0$  for  $pd=\pi$ .

Fig. 2, with the linear term in the phase removed, and (10) yield information about harmonic distortion. If  $2b(\omega_c-\omega_1)=n\pi$ ,  $n$  integral, then  $\omega_c$  is at the peak of an amplitude wiggle, and the sidebands fall at points that are symmetrical with respect to this peak. In this case, (10) shows that  $D_{kA}=0$  for  $k$  even. If  $2b(\omega_c-\omega_1)=(2n+1)\pi/2$ , then  $\omega_c$  is at a node and the points for the sidebands are odd symmetrical about this node. In this case,  $D_{kA}=0$  for  $k$  odd. If  $2d(\omega_c-\omega_2)=n\pi$  then  $\omega_c$  is at a node, and the sideband points are distributed with odd symmetry about this node. For this case,  $D_{k\phi}=0$  for  $k$  even. Finally, if  $2d(\omega_c-\omega_2)=(2n+1)\pi/2$ , then  $\omega_c$  is at a maximum or minimum, and there is even symmetry for the sideband points. For this case,  $D_{k\phi}=0$  for  $k$  odd.

A thorough analytical and numerical discussion of the distortion results in (10) and (14) will not be given in this paper. Since such a discussion is very complicated and probably of no practical value in general form, it will be made later for the special case of the waveguide. However, one interesting statement can be made about  $D$  in general.

If neither  $pb$  nor  $pd$  is close to  $n\pi/2$  and  $m$  is sufficiently large, then approximately

$$\left. \begin{aligned} D_A &\approx \mathcal{E}_1 \sin pb, \\ D_\phi &\approx \mathcal{E}_2 \sin pd, \\ D^2 &\approx \mathcal{E}_1^2 \sin^2 pb + \mathcal{E}_2^2 \sin^2 pd, \end{aligned} \right\} \quad (15)$$

for  $pb$  and  $pd$  unequal to  $n\pi/2$  for any integral  $n$  and for large  $m$ .

It will be seen later in the case of the waveguide that  $D$  in (15) is close to its maximum value for a given value of  $pb$  ( $b=d$  in this special case) and that the over-all maximum value of  $D$  is close to its value in (15) for  $pb=\pi/2$ . It is possible that similar conclusions may apply to the general case. If this is true, then (15) indicates over-all maxima of  $D_A=\mathcal{E}_1$ ,  $D_\phi=\mathcal{E}_2$ , and  $D^2=\mathcal{E}_1^2+\mathcal{E}_2^2$ . For example, if  $\mathcal{E}_1=\mathcal{E}_2=0.05$ , then  $D_A=D_\phi=0.05$  and  $D=0.07$ . It can readily be shown from (14) that, for  $pb \neq n\pi/2$  and  $pd \neq n\pi/2$ ,  $D_A$  and  $D_\phi$  have maxima and minima with respect to  $2b(\omega_c-\omega_1)$  and  $2d(\omega_c-\omega_2)$  at  $4b(\omega_c-\omega_1)=n\pi$  and  $4d(\omega_c-\omega_2)=n\pi$ . The two  $n$ 's need not refer to the same integer.

This concludes the general discussion of the first-order analysis of distortion caused by sinusoidal wiggles in amplitude and phase of transmission systems. If the mathematical description of such wiggles in the essential band of frequencies for the input frequency-modulated wave requires more than one sinusoid, the deriva-

tion of distortion results becomes more complicated, but remains possible along the lines of the previous analysis.

### III. DERIVATION OF WAVEGUIDE AMPLITUDE AND PHASE CHARACTERISTICS

We now apply previously obtained distortion results to lossless waveguides. Fig. 3 shows their equivalent transmission-line representation. It is possible to derive the special forms that the distortion expressions take for the waveguide by regarding the output voltage  $E_2$  as being composed of voltages due to the main incident wave and the first re-reflection. The first-order analysis of this report would imply that the remaining re-reflections can be neglected. This point of view can be justified by using the paired-echo method or by superposing the main incident wave and the first re-reflection for each frequency in the input frequency-modulation spectrum. Harmonic-distortion formulas derived from this point of view appear as sideproducts in articles on multipath transmission by Crosby<sup>1</sup> and Corrington.<sup>2</sup>

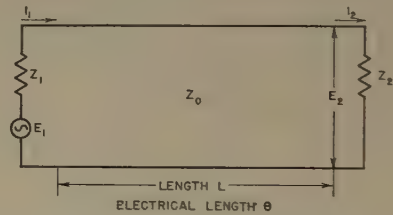


Fig. 3—Terminated waveguide.

Now consider the waveguide of Fig. 3. To apply previous distortion results to the waveguide, the quantities  $b$ ,  $c$ ,  $d$ ,  $\omega_1$ ,  $\omega_2$ ,  $\mathcal{E}_1$ , and  $\mathcal{E}_2$  have to be expressed in terms of waveguide parameters. From Fig. 3 and standard transmission-line equations, one can express  $E_2$  in terms of a constant-voltage generator  $E_1$  by the relation

$$\begin{aligned} E_2 &= \frac{Z_1 Z_2}{(Z_1 + Z_2) \cos \theta + j(1 + Z_1 Z_2) \sin \theta} E_1 \\ &= A(\theta) e^{-j\phi(\theta)} E_1. \end{aligned} \quad (16)$$

The impedances  $Z_1$  and  $Z_2$  in (24) have been normalized with respect to the characteristic impedance  $Z_0$  of the waveguide.

For real  $Z_1$  and  $Z_2$ , one can write

$$\left. \begin{aligned} A(\theta) &= \frac{Z_1 Z_2}{[(Z_1 + Z_2)^2 + (1 - Z_1^2)(1 - Z_2^2) \sin^2 \theta]^{1/2}} \\ \tan \phi(\theta) &= \frac{1 + Z_1 Z_2}{Z_1 + Z_2} \tan \theta. \end{aligned} \right\} \quad (17)$$

<sup>1</sup> M. G. Crosby, "Frequency-modulation propagation characteristics," Proc. I.R.E., vol. 24, pp. 898-913; June, 1936.

<sup>2</sup> M. S. Corrington, "Frequency-modulation distortion caused by multipath transmission," Proc. I.R.E., vol. 33, pp. 878-891; December, 1945.

It is convenient to rewrite (17) in terms of reflection factors  $r_1$  and  $r_2$  defined by

$$\left. \begin{aligned} r_1 &= \frac{1 - Z_1}{1 + Z_1}, & Z_1 < 1 \\ r_2 &= \frac{1 - Z_2}{1 + Z_2}, & Z_2 < 1. \end{aligned} \right\} \quad (18)$$

If  $Z_1$  or  $Z_2$  is greater than one (or both are), then the numerators in (18) are reversed, but the final results are not affected.

With the use of (18), (17) becomes

$$\left. \begin{aligned} A(\theta) &= \frac{(1 - r_1)(1 - r_2)}{2[(1 - r)^2 + 4r \sin^2 \theta]^{1/2}}, & r = r_1 r_2 \\ \tan \phi(\theta) &= \frac{1 + r}{1 - r} \tan \theta. \end{aligned} \right\} \quad (19)$$

Before proceeding, consider the picture of distortion if either load in Fig. 3 is matched, i.e., if  $r_1 = 0$  or  $r_2 = 0$ . In either case,  $A(\theta)$  reduces to a constant and  $\phi$  becomes  $\theta$ . Since  $\theta$  is approximately linear in frequency  $\omega$ ,  $\phi$  becomes linear in  $\omega$ . In other words, for  $r = 0$ , the system has a flat amplitude characteristic and linear phase characteristic. Hence, as is well known for this case, the system will not distort the frequency of a frequency-modulated input. If  $r \neq 0$ , then energy from the generator travels back and forth between  $Z_1$  and  $Z_2$  and undergoes partial reflections at each end. The energy at the load end comes from the main incident wave and reflections. It is the latter that cause distortion trouble in the case of a frequency-modulated input.

If now  $r$  is assumed to be small, it can be shown that (19) becomes

$$\left. \begin{aligned} A(\theta) &\approx 1 + r \cos 2\theta, \\ \phi(\theta) &\approx \theta + r \sin 2\theta. \end{aligned} \right\} \quad (20)$$

There remains the problem of expressing  $\theta$  in terms of  $\omega$ . Waveguide theory yields the formula

$$\theta = \frac{L\omega}{v} \left[ 1 - \frac{(\omega_1)^2}{(\omega)^2} \right]^{1/2} = a\omega, \quad (21)$$

where  $L$  is the physical length of the guide,  $v$  is velocity of light in unbounded space of the waveguide medium, and  $\omega_1$  is the cutoff frequency of the propagated mode. If  $\omega$  is restricted to a small band, then the radical can be assumed to have a constant value taken at the center of the band, so that  $a$  is essentially constant. The use of (21) in (20) leads to the expressions

$$\left. \begin{aligned} A(\omega) &= 1 + r \cos 2a\omega, \\ \phi(\omega) &= a\omega + r \sin 2a\omega. \end{aligned} \right\} \quad (22)$$

#### IV. DISTORTION FORMULAS FOR WAVEGUIDE

If (22) is compared to (2), it is seen that  $\mathcal{E}_1 = \mathcal{E}_2 = r$ ,  $b = c = d = a$ , and  $\omega_1 = \omega_2 = 0$ . The variable part of the output frequency as given by (11) thus becomes

$$\left. \begin{aligned} \frac{1}{p} \frac{d\psi}{d\tau} &= m \cos p\tau \\ &+ 2r \sin 2a\omega_c \sum_{k=2,4,\dots}^{\infty} k J_k(2m \sin ap) \\ &\sin k(p\tau - pa - \pi/2) \\ &+ 2r \cos 2a\omega_c \sum_{k=3,5,\dots}^{\infty} k J_k(2m \sin ap) \\ &\cos k(p\tau - pa - \pi/2). \end{aligned} \right\} \quad (23)$$

The general distortion formulas in (12) now become

$$\left. \begin{aligned} D/2^{1/2}r &= \left\{ \sin^2 ap \left\{ 1 + [J_0(4m \sin ap) \right. \right. \\ &\quad \left. \left. + J_2(4m \sin ap) \right] \cos 4a\omega_c \right\} \right. \\ &\quad \left. - (2/m^2) J_1^2(2m \sin ap) \cos^2 2a\omega_c \right\}^{1/2}, \\ D_2 &= (4r/m) J_2(2m \sin pa) \sin 2a\omega_c, \\ D_3 &= (6r/m) J_3(2m \sin pa) \cos 2a\omega_c \dots \end{aligned} \right\} \quad (24)$$

In interpreting the distortion results in (24), it is instructive to consider Fig. 4. The wiggles in Fig. 4 are phased 90 degrees apart, have amplitude  $r$ , and have

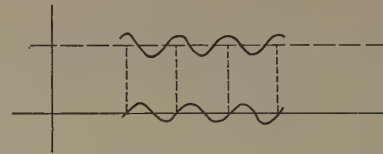


Fig. 4—Amplitude and phase characteristics of a terminated waveguide. The upper curve corresponds to  $A(\omega) = 1 + r \cos 2a\omega$  and the lower curve to  $\phi(\omega) = r \sin 2a\omega$  with the linear term omitted.

period  $\pi/a$  in  $\omega$ . The discussion following (14) can be applied here. It leads to the conclusions that there is odd-harmonic distortion if  $2a\omega_c = n\pi$ , even-harmonic distortion if  $4a\omega_c = (2n+1)\pi$ , and no distortion if  $ap = n\pi$ .

It is interesting to examine (24) in limiting cases. If  $m \sin ap$  is very small, either because of small  $m$  or because of small  $ap$ , and if  $\sin 2a\omega_c \neq 0$ , then it can be seen that (24) reduces to

$$D \approx 2rm \sin^2 ap \sin 2a\omega_c \approx D_2, \quad (25)$$

for  $m \sin ap$  small and  $\sin 2a\omega_c \neq 0$ .

In this case, distortion is chiefly of the second-harmonic type. If  $m \sin ap$  is small and  $\sin 2a\omega_c = 0$ , then (24) reduces to

$$D \approx rm^2 \sin^3 ap \approx D_3 \text{ for } m \sin ap \text{ small and } \sin 2a\omega_c = 0. \quad (26)$$

Here, distortion is primarily of the third-harmonic type. Note that, for small  $m \sin ap$  and  $\sin 2a\omega_c = 0$ , distortion drops much more rapidly with  $m \sin ap$  than for the case  $\sin 2a\omega_c \neq 0$ .

If  $m \sin ap$  is large, then (24) becomes

$$D \approx 2^{1/2}r \sin ap. \quad (27)$$

This result is essentially independent of  $m$  and  $\omega_c$ . It cannot be attributed primarily to any single harmonic.

A brief discussion will now be given of the total distortion  $D$ . It depends on the dimensionless parameters  $r$ ,  $ap$ ,  $a\omega_c$ , and  $m$ . Since  $D$  varies linearly with  $r$ , no further discussion of its dependence on  $r$  is required. Perhaps the most striking feature about (24) is that  $D$  is periodic with fundamental period  $\pi$  in either  $ap$  or  $2a\omega_c$  for fixed  $m$ . In other words,  $D$  cannot increase indefinitely with  $ap$  or  $2a\omega_c$ , but passes periodically through zeros and maxima. Since  $a$  is linear in waveguide length  $L$ , increasing  $L$  indefinitely does not produce an indefinitely increasing  $D$ .

It appears at first glance from the foregoing that the description of distortion in the waveguide as a long-line effect is inaccurate. However, as will be seen later, the first maximum of  $D$  with respect to  $L$  for fixed  $p$ ,  $\omega_c$ , and  $m$  may occur for a large value of  $L$ , so that increasing  $L$  from zero to this value will produce monotonically increasing  $D$ . In this case, increasing distortion can be regarded as a long-line effect so far as physical length  $L$  is concerned, but is actually confined to electrical lengths  $ap < \pi$ .

#### V. CONSTRUCTION OF DISTORTION GRAPHS FOR WAVEGUIDES

A picture of the distortion introduced by loaded waveguides can be obtained by plotting distortion  $D$  against physical length  $L$  of waveguide or audio frequency  $f_a$ . Assume that the carrier frequency is fixed at 5,000 mc. Assume also that the maximum instantaneous deviation in the frequency of the frequency-modulated input is fixed. For this case, the index  $m$  varies with audio frequency  $f_a = p/2\pi$ . Assume that  $m=1$  when  $f_a=10$  mc, so that  $m=10^7/f_a$  for any other audio frequency  $f_a$ .

Now consider the expression given for  $a$  in (21). The cutoff frequency  $\omega_1$  for the lowest mode in a standard 2-inch by 1-inch waveguide is about  $2\pi \times 3.16 \times 10^9$ . The value of the radical in (21) is about 0.775 for  $\omega = \omega_c$ . The value of  $a$  is therefore given by  $a = 7.87 \times 10^{-10} L$ , seconds, for  $L$  in feet. The expressions for  $ap$ ,  $a\omega_c$ , and  $m$  to be used in the distortion formulas (24) for the present case become

$$\left. \begin{aligned} 2a\omega_c &= 2\pi \times 7.87L, \\ ap &= 2\pi \times 7.87 \times 10^{-10} f_a L, \\ m &= 10^7/f_a. \end{aligned} \right\} \quad (28)$$

Equation (28) shows that the functions of  $2a\omega_c$  and  $ap$  in (24) have respective periods of 0.0635 feet and  $0.0635 \times 10^{10}/f_a$  feet in  $L$ . In other words, the period of the  $ap$  terms is  $10^{10}/f_a$  times the period of the  $2a\omega_c$  terms. Since  $f_a \leq 10^7$  in the present application, the terms involving  $2a\omega_c$  in (24) have a high frequency compared to those involving  $ap$ . Equation (28) also shows that the functions of  $ap$  in (24) have period  $6.35 \times 10^8/L$  cycles in  $f_a$ . Note that the functions of  $2a\omega_c$  in (24) are independent of  $f_a$ .

Graphs are provided in Figs. 5 and 6 of  $D/2^{1/2}r$  against waveguide length  $L$  for different values of audio frequency  $f_a$  and against  $f_a$  for different values of  $L$ . Consider first the plots in Fig. 5 of  $D/2^{1/2}r$  against  $L$  for different values of  $f_a$ . For large values of  $f_a$ , these

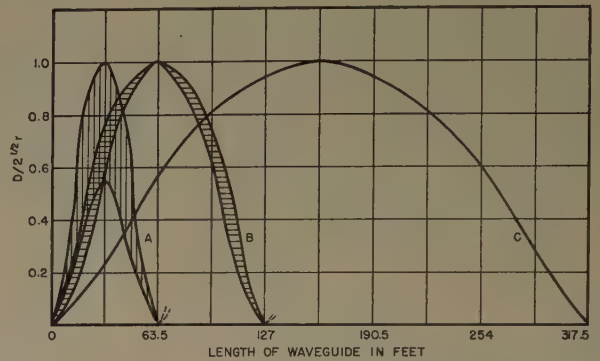


Fig. 5—Total distortion  $D$  plotted against waveguide length  $L$ . Curves A are for  $f_a=10$  mc, and  $m=1$ ; B,  $f_a=5$  mc, and  $m=2$ ; C,  $f_a=2$  mc, and  $m=5$ .

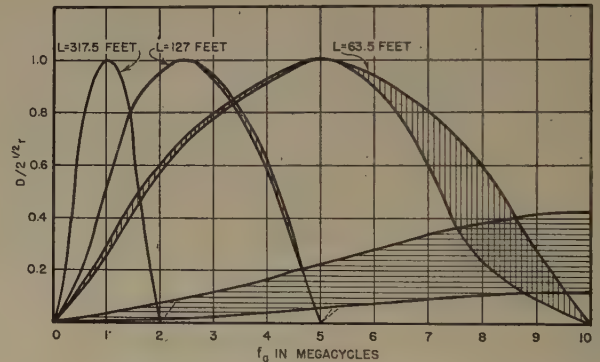


Fig. 6—Total distortion  $D$  plotted against audio frequency  $f_a$  with  $m=10/f_a$ .

graphs show a shaded area bounded by two curves. The actual curve lies in this shaded area and has high-frequency wiggles that have not been indicated. Hence, for large  $f_a$ ,  $D$  changes very rapidly for a slight change in  $L$ . As noted above, these high-frequency wiggles have a period of 0.0635 feet in  $L$  independently of  $f_a$ . In the graph for  $f_a=10$  mc, for example, there are 1,000 wiggles in the shaded area. The amplitude of these wiggles tends to zero as  $f_a$  is decreased, and hence  $m$  is increased. Only one period of each curve is drawn in Fig. 5.

Next consider the plots in Fig. 6 of  $D/2^{1/2}r$  against  $f_a$  for various values of  $L$ . For small values of  $L$ , these graphs show shaded areas that are interpreted differently from the shaded areas of Fig. 5. In the present case, any actual curve again lies within the corresponding shaded area but no longer has any wiggles. A slight change in the parameter  $L$  from 0 to 0.0635 feet will yield a distortion curve without wiggles anywhere in a shaded area. Notice that these shaded areas shrink vertically as  $L$  is increased. As in Fig. 5, only one period of each curve is drawn in Fig. 6.

# Measurements of Wavelengths and Attenuation in Dielectric Waveguides for Lower Modes\*

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**Summary**—The wavelength of a wave guided by a dielectric rod has been measured for the  $TE_{0n}$ ,  $TM_{0n}$ ,  $HE_{1n}$ , and  $EH_{1n}$  modes for  $n=1$  and 2. The measurements were made on polystyrene, lucite, textolite, and paraffin rods, as well as on plastic tubes filled with Nu-jol and dioxane. The measurements agree very well with the solutions of the characteristic equation. The solution of the characteristic equation corresponding to the second radial mode and the angular mode of order one has two branches, both of which are found experimentally. Measurements are made of the attenuation in a dielectric rod due to losses in the dielectric and due to bending of the dielectric guide.

## I. INTRODUCTION

MANY WORKERS, including Zahn,<sup>1</sup> Schriever,<sup>2</sup> Southworth,<sup>3</sup> Mallach,<sup>4</sup> and Chandler<sup>5</sup> have measured the properties of dielectric waveguides. However, most of these measurements were made on small rods which could support only the first-order radial modes. Hondros and Debye,<sup>6</sup> Carson, Mead, and Schelkunoff,<sup>7</sup> Wegener,<sup>8</sup> Bondi and Pryce,<sup>9</sup> Whitmer,<sup>10</sup> Abele,<sup>11</sup> Elsasser,<sup>12</sup> Stratton,<sup>13</sup> and others have studied the theoretical aspects of the dielectric wave-

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<sup>1</sup> H. Zahn, "Über den Nachweis elektromagnetischer Wellen an dielektrischen Drähten," *Phys. Zeitsch.*, vol. 16, pp. 414-416; November 15, 1915.

<sup>2</sup> O. Schriever, "Elektromagnetische Wellen an dielektrischen Drahten," *Ann. d. Phys.*, vol. 63, pp. 645-673; 1920.

<sup>3</sup> G. C. Southworth, "Hyper-frequency wave guides—general considerations and experimental results," *Bell Sys. Tech. Jour.*, vol. 15, pp. 284-309; April, 1936.

<sup>4</sup> Peter Mallach, "Air material command report, F-TS-2223-RE," February, 1948. Translated by P. L. Harbury.

<sup>5</sup> C. H. Chandler, "An investigation of dielectric rod as wave guide," *Jour. Appl. Phys.*, vol. 20, pp. 1188-1196; December, 1949.

<sup>6</sup> D. Hondros, and P. Debye, "Elektromagnetische Wellen an dielektrischen Drähten," *Ann. d. Phys.*, vol. 32, pp. 465-476; 1910.

<sup>7</sup> J. R. Carson, S. P. Mead, and S. A. Schelkunoff, "Hyper-frequency wave guides—mathematical theory," *Bell Sys. Tech. Jour.*, vol. 15, pp. 310-333; April, 1936.

<sup>8</sup> H. J. Wegener, "Propagation velocity, wave resistance, and attenuation of electromagnetic waves in dielectric cylinders," Air Material Command Microfilm ZWB/FB/Re/2018, R. 8117 P 831. The first and third parts have been translated by M. M. Astrahan and W. C. Jakes, Jr., of the Microwave Laboratory, Northwestern University.

<sup>9</sup> H. Bondi and M. H. L. Pryce, "Dielectric cylinders as waveguides," Admiralty Signal Establishment Report No. M.434, August, 1942.

<sup>10</sup> R. Whitmer, "Fields in nonmetallic waveguides," *Proc. I.R.E.*, vol. 36, pp. 1105-1109; September, 1948.

<sup>11</sup> M. Abele, "Teoria della propagazione di un campo elettromagnetico lungo una guida dielettrica a sezione circolare," *Il Nuovo Cimento*, vol. 5, pp. 3-13; August, 1948.

<sup>12</sup> Walter M. Elsasser, "Attenuation in a dielectric circular rod," *Jour. Appl. Phys.*, vol. 20, pp. 1193-1196; December, 1949.

<sup>13</sup> J. A. Stratton, "Electromagnetic Theory," McGraw-Hill Book Co., Inc., New York, N. Y., pp. 524-527; 1941.

guide, but no comprehensive discussion of the theory has been published.

In the following discussion the wavelength of the guided wave will be described<sup>14</sup> by an "apparent index of refraction," which is defined as  $\lambda_{\text{guide}}/\lambda_{\text{external}}$  medium and denoted by  $n_a$ . The value of  $n_a$  may be measured or it may be computed from the characteristic equation given by Stratton.<sup>15</sup>

## II. EXPERIMENTAL TECHNIQUE

The desired modes were first generated in metallic waveguides by means of mode converters, and the dielectric rod was tapered to fit the metallic guide. Three different methods were used to measure the guided wavelength.

In the first method the waveguide was terminated by a large copper sheet perpendicular to the axis of the guide. This sheet produced a large standing-wave ratio that could be measured easily with a moving probe. Small rods yielded a simple standing wave which could be measured accurately. In the case of large rods, the tapered section that served as a transition between the metallic and the dielectric guide was short enough to give rise to a second, and in some cases a third, radial mode. When this happened, the standing-wave pattern had a modulation envelope, as shown in Fig. 1, from which one can determine the guided wavelength for both modes.

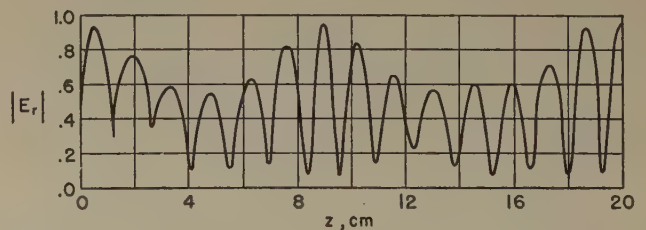


Fig. 1—The dependence of  $|E_r|$  on the distance along a dielectric rod which has two modes,  $TM_{01}$  and  $TM_{02}$ , of propagation. The rod is made of textolite, and has a diameter of 2 5/16 inches. The free-space wavelength is 3.20 cm.

The second method is a variation of a procedure used by Chandler.<sup>16</sup> In this method a hole is cut in each of two copper plates which are mounted perpendicularly to the dielectric rod that passes through the holes. When the distance between the plates is properly adjusted, a resonant cavity results. This method will be referred to as the "resonator method (moving plates)." It works well on rods of small diameter, for which most

<sup>14</sup> Gilbert Wilkes, "Wavelength lenses," *Proc. I.R.E.*, vol. 36, pp. 206-212; February, 1948.

<sup>15</sup> See Eq. (9), p. 526, of footnote reference 13.

<sup>16</sup> See Fig. 3, p. 1190, of footnote reference 5.

of the energy is outside of the rod, but it is not suitable for use on large rods.

In order to apply the resonator method to large rods, it is necessary to make the holes in the copper sheets smaller than the dielectric rod so that the sheets could reflect a significant amount of the energy. The dimensions of the dielectric rod that was placed between the two plates were calculated in advance from the characteristic equation. This made it necessary to tune the klystron oscillator through a small frequency range only. This method will be referred to as the "resonator method (fixed plates)."

In all of the measurements the source of energy was a type TS-13 microwave signal generator operating near a frequency of 9,275 mc, and the detector was a crystal detector in conjunction with a high-gain amplifier. The index of refraction of the samples used was measured at the operating frequency by transmission and reflection methods.<sup>17</sup>

### III. THE $TE_{0n}$ MODE

Fig. 2 is a graph of some of the roots of the characteristic equation that governs the propagation of the  $TE_{0n}$  mode along a rod whose index of refraction is 1.5. The  $TE_{01}$  mode transducer did not function well, and only three reliable measurements were obtained. These measurements gave values of 1.03, 1.13, and 1.23 for  $n_a$  corresponding to values of 0.596, 0.796, and 1.00 for  $d/\lambda_0$ , respectively. Here  $d$  is the diameter of the rod which was made of lucite with  $n = 1.60$ .

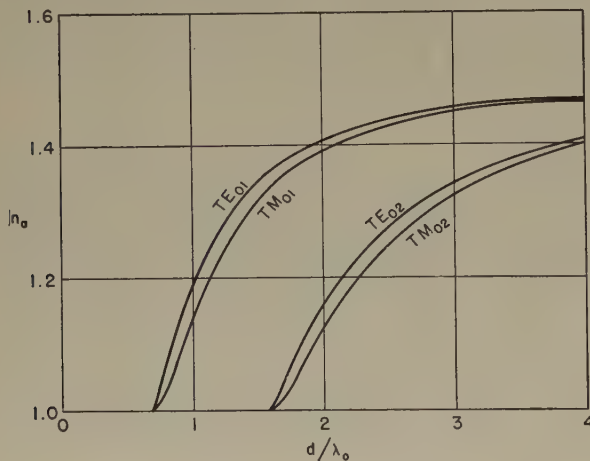


Fig. 2—Theoretical curves of  $n_a$  versus  $d/\lambda_0$  for a rod whose index of refraction is 1.5. The  $TE_{0n}$  and the  $TM_{0n}$  modes.

### IV. THE $TM_{0n}$ MODE

Fig. 2 also shows some of the roots of the characteristic equation that governs the propagation of the  $TM_{0n}$  mode along a rod whose index of refraction is 1.5. Fig. 3 shows some experimental data for lucite and textolite rods and for a polystyrene tube containing Nujol.

<sup>17</sup> Carol G. Montgomery, "Technique of Microwave Measurements," McGraw-Hill Book Co., Inc., New York, N. Y., Chapt. 10; 1947.

The walls of the polystyrene tube were 1/16 inch thick. Nujol was used because it has an index of refraction of 1.5 corresponding to the theoretical curves shown in Fig. 2. The indices of refraction of the textolite and lucite rods were 1.58 and 1.60, respectively. The  $TM_{01}$  mode in the circular metallic waveguide was transformed from a  $TE_{10}$  mode in a rectangular waveguide by means of a suitable junction.

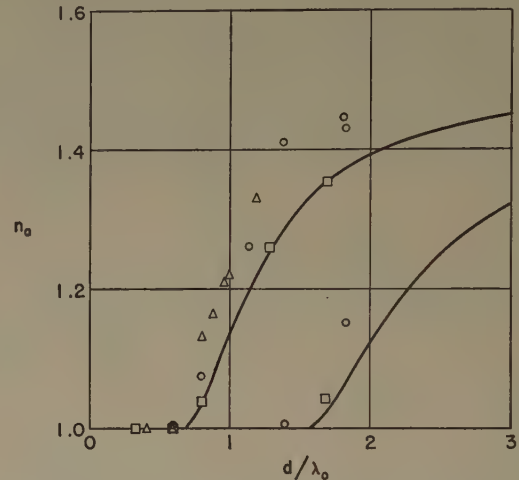


Fig. 3—Measurements of  $n_a$  versus  $d/\lambda_0$  for the  $TM_{0n}$  mode.  $\circ$  textolite ( $n = 1.58$ ).  $\triangle$  lucite ( $n = 1.60$ ).  $\square$  polystyrene tubes filled with Nujol ( $n = 1.50$ ). The solid curve is a theoretical curve for  $n = 1.5$  and should be compared with the squares only. The data for textolite were measured by the resonator method (moving plates), while the other data were obtained with the probe method.

### V. THE $EH_{1n}$ AND THE $HE_{1n}$ MODES

The mode with angular order one is of more practical importance than the modes with no angular variation; consequently, it has been discussed more fully in the literature. Bondi and Pryce<sup>18</sup> have pointed out that the angular mode  $n = 1$  is unique in that it is the only mode for which a rod of arbitrarily small diameter can propagate a guided wave. Bondi and Pryce<sup>19</sup> call this mode the "fundamental mode," while Wegener<sup>20</sup> refers to it as the " $HE_{10}$  mode." This designation is changed to  $HE_{11}$  in the present paper. The higher radial modes occur in pairs, as shown in Fig. 4, which is a plot of some of the roots of the characteristic equation. Wegener<sup>20</sup> says that these higher modes will be called " $HE$  waves" if the field structure of a cross section resembles that of an  $H$  wave and  $EH$  waves if it resembles that of an  $E$  wave." Although this description of the difference does not seem adequate, a comparison of Figs. 2 and 4 indicates that it is justifiable to characterize the two radial modes as Wegener suggests. This distinction is placed on a firmer basis by Abele,<sup>21</sup> who shows that the coefficients of the components of the transverse electric field have different signs on the two branches associated with each radial mode.

<sup>18</sup> See p. 2 of footnote reference 9.

<sup>19</sup> See p. 1 of footnote reference 9.

<sup>20</sup> See p. 9 of the translation of footnote reference 8.

<sup>21</sup> See pp. 9-10 of footnote reference 11.

Fig. 4 is a graph of some of the roots of the characteristic equation for the angular variation of order one and for the first two radial modes. The detailed structure of the second radial mode does not appear to have been illustrated before. The curves are computed for  $n=1.5$ . In order to check the theoretical solution of the characteristic equation that is shown in Fig. 4, a series of paraffin blocks were molded and measured by the resonator method (fixed plates). The resulting data are shown in Fig. 4.

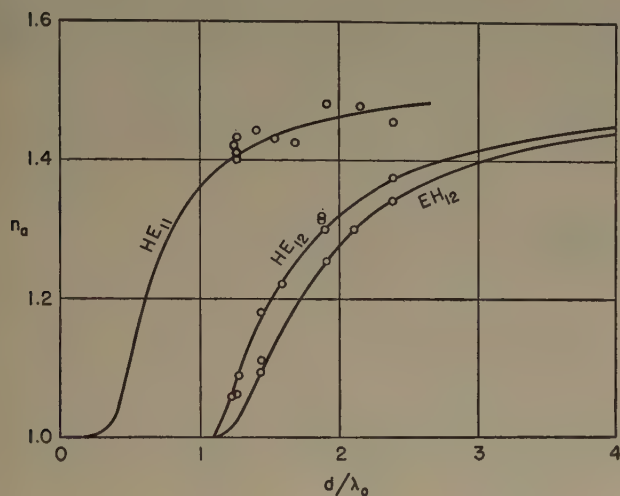


Fig. 4—Measurements of  $n_a$  versus  $d/\lambda_0$  for paraffin ( $n=1.50$ ) by means of the resonator method (fixed plates). The solid curves are theoretical.

Fig. 5 shows further data on the  $HE_{11}$  mode for lucite and textolite rods and for polystyrene tubes filled with Nujol and dioxane. The dielectric constant of the dioxane solution was 1.60. Since the behavior of the  $HE_{11}$

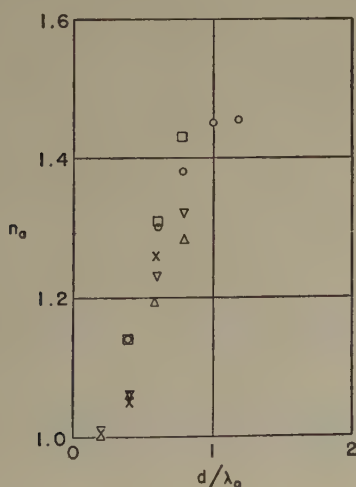


Fig. 5—Measurements of  $n_a$  versus  $d/\lambda_0$  for the  $HE_{11}$  modes for various rods.  $\circ$  lucite ( $n=1.60$ ) measured by the probe method.  $\square$  lucite ( $n=1.60$ ) measured by the resonator method (moving plates).  $\times$  textolite ( $n=1.58$ ) measured by the resonator method (moving plates).  $\Delta$  polystyrene tubes filled with Nujol ( $n=1.50$ ) measured by the probe method.  $\triangle$  polystyrene tubes filled with dioxane ( $n=1.60$ ) measured by the probe method. The source was a circular metallic waveguide with the  $TE_{11}$  mode in every case except that of the squares which were obtained from a  $TM_{11}$  mode.

mode should be independent of the source, the lucite rods were excited by using both a  $TM_{11}$  mode and a  $TE_{11}$  wave in the metallic waveguide.

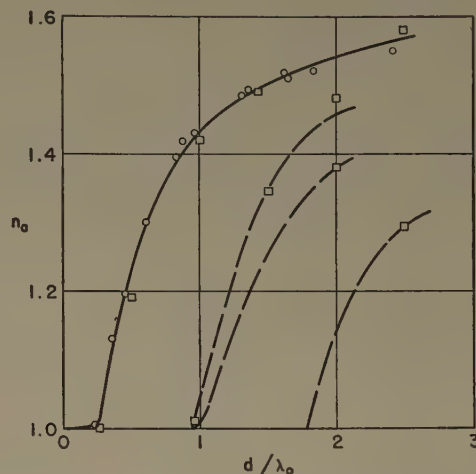


Fig. 6—Measurements of  $n_a$  versus  $d/\lambda_0$  for polystyrene ( $n=1.60$ ).  $\circ$  resonator method (fixed plates)  $\square$  probe method. The curves are based on the experimental data.

Fig. 6 represents a series of measurements on polystyrene rods by the resonator (fixed plates) and the probe methods. The cutoff frequencies for the first three radial modes occur at  $d/\lambda_0 = 0, 0.97$ , and  $1.79$ .

The  $TE_{11}$  modes were generated in the circular metallic waveguides by a simple tapered transition from a  $TE_{10}$  mode in a rectangular waveguide. The  $TM_{11}$  mode was generated in the circular metallic guide by means of two axial probe antennas excited  $180^\circ$  out of phase.

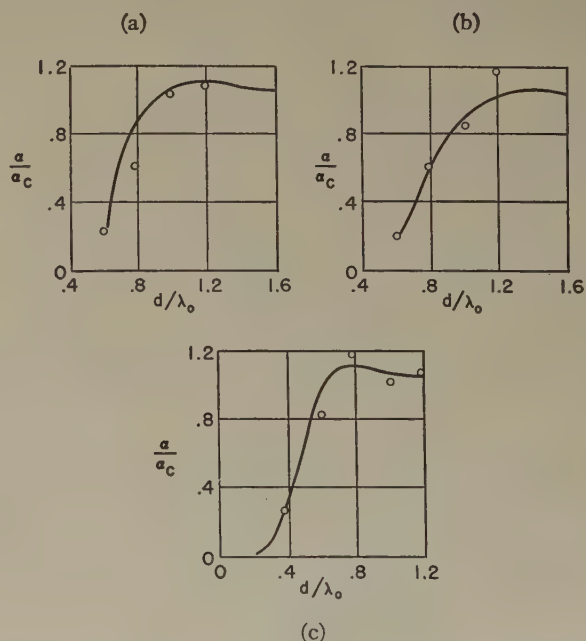


Fig. 7—The dependence of the attenuation of a lucite rod on the diameter. (a)  $TE_{01}$  mode. (b)  $TM_{01}$  mode. (c)  $HE_{11}$  mode.  $\alpha_a$  is the attenuation in coaxial cable filled with lucite. The solid curves are from Wegener's theoretical work.

## VI. ATTENUATION

Wegener<sup>22</sup> has computed the attenuation in a dielectric waveguide caused by the losses in the dielectric. Fig. 7 shows his theoretical curves and experimental data for a series of lucite rods. The lucite used in these experiments has a loss factor given by  $\tan \delta = 0.01$ .

It is frequently suggested that flexible dielectric guides can be used as connections to join sections of metallic guides. Fig. 8 shows the attenuation that results when two parallel waveguides separating a vertical distance  $h$  are connected with a flexible vinyl tube filled

with Nujol. The tube is 2 feet long and has an outside diameter of 9/16 inch.

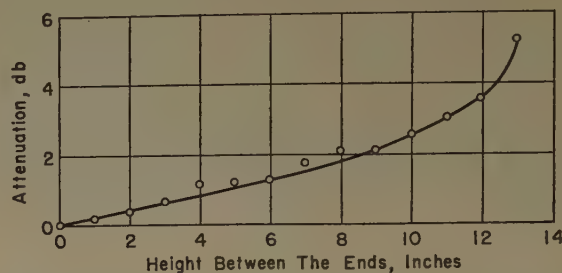


Fig. 8—The attenuation of a vinyl tube (od 9/16 inch) filled with Nujol ( $n=1.50$ ) as a function of the height between the ends. The data are for the  $HE_{11}$  mode.

<sup>22</sup> See Figs. 13, 14, and 15 of footnote reference 8



## The Short-Slot Hybrid Junction\*

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**Summary**—This paper describes a novel high-performance x-band hybrid junction. Its over-all dimensions are  $1\frac{1}{2}'' \times \frac{1}{2}'' \times 2''$ . It consists of a suitably loaded gap in the narrow common wall between two  $\frac{1}{2}'' \times 1''$  waveguides. Over the frequency range 8,500- to 9,600-mc per second power equality within  $\pm 0.25$  decibels, isolation in excess of 30 decibels and a standing-wave ratio less than 1.07 may be obtained. The theory of the device is explained, and the particular advantages of this hybrid junction for a number of applications are outlined.

### INTRODUCTION

THE WAVEGUIDE hybrid junction<sup>1</sup> plays an important part in a number of specialized waveguide circuits. In addition to its application as a power splitter, it is useful in the construction of balanced duplexers,<sup>2</sup> balanced mixers,<sup>3</sup> and broad-band switches.<sup>4</sup> Although special forms of waveguide hybrids have been used on occasion, the most common are the "magic tee" and the "hybrid ring." Both of these have in common the characteristic that when power enters one of the terminals it divides between two of the others so that

the outgoing voltages at equally distant terminals are either in phase or exactly out of phase. There exists, however, another large class of waveguide hybrid junctions at whose equidistant output terminals the voltages are always in quadrature. One of the earliest of these has been called a right-angle hybrid.<sup>5</sup> The possibility of quadrature hybrid junctions having broad-band characteristics has been pointed out by N. I. Korman, in an unpublished work, and by Riblet and Saad.<sup>6</sup> For many applications, however, these junctions are unduly large. It is the object of this article to describe a compact broad-band hybrid junction of the quadrature type which lends itself, for many applications, to more efficient use of space than is possible with conventional hybrids.

Although the short-slot hybrid is closely related to the family of directional couplers, it is not, strictly speaking, a member according to the definition given by Mumford.<sup>7</sup> Nevertheless, a structure which has the same general appearance but which is a directional coupler has been described by Surdin.<sup>8</sup> Moreover, the feasibility of obtaining hybrid performance from paral-

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† Microwave Development Laboratories, Inc., Waltham, Mass.  
<sup>1</sup> W. A. Tyrrell, "Hybrid circuits for microwave," *PROC. I.R.E.*, vol. 35, pp. 1307-1313; November, 1947.

<sup>2</sup> J. Reed, "Rat Race Duplexing," M.I.T. Radiation Laboratory Report 885; February, 1946.

<sup>3</sup> W. A. Tyrrell, *ibid.*

<sup>4</sup> W. D. Lewis, and L. C. Tillotson, "A non-reflecting branching filter for microwaves," *Bell Sys. Tech. Jour.*, pp. 83-84; January, 1948.

<sup>5</sup> C. W. Zabel, "Balanced Duplexers," *Microwave Duplexers*, Radiation Laboratory Series, McGraw-Hill Book Co., New York, N.Y., vol. 14, p. 367; 1948.

<sup>6</sup> H. J. Riblet and T. S. Saad, "A new type of waveguide directional coupler," *PROC. I.R.E.*, vol. 36, p. 64; January, 1948.

<sup>7</sup> W. W. Mumford, "Directional couplers," *PROC. I.R.E.*, vol. 35, pp. 160-166; February, 1947.

<sup>8</sup> M. J. Surdin, "Directional couplers in waveguides," *Jour. IEE* (London), pt. III, A 931 (no. 4) pp. 735-736; 1946.

lel waveguides apertured by a single large hole is suggested by Dicke.<sup>9</sup>

### SIMPLE GENERAL THEORY<sup>10</sup>

To date all directional coupler-like hybrid junctions have had a plane of symmetry running their full length. Such an arrangement is shown schematically in Fig. 1. When power is incident on the main guide 2 at terminal 2<sub>i</sub>, it proceeds along that waveguide until it encounters the coupling section. Under suitable conditions, by the time the energy reaches the end of the coupling section, it will have divided so that the energy leaving at terminal 1<sub>o</sub> just equals that leaving at 2<sub>o</sub>. If in addition no power leaves at terminal 1<sub>i</sub> and none is reflected at terminal 2<sub>i</sub>, assuming perfectly matched terminations at 1<sub>o</sub> and 2<sub>o</sub>, the structure is an ideal waveguide hybrid junction.

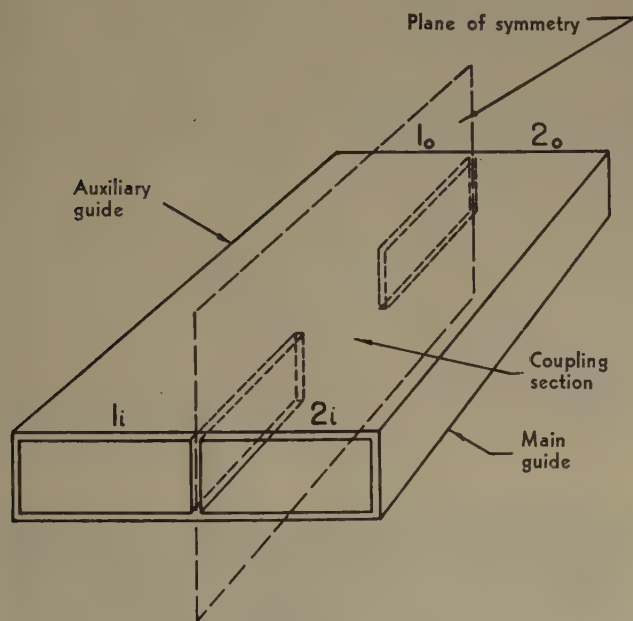


Fig. 1—Schematic hybrid junction.

It is now rather easy to derive several of the important characteristics of this type of hybrid junction and to state certain fundamental conditions which must be satisfied.

Since the reader should have no difficulty in reconstructing the arguments with the help of the Lippmann and Kyhl references, the results will be presented without details.

Conditions for complete isolation: *The reflected voltages in the even and odd modes shall both be zero.* When

this condition is satisfied, the condition for power division becomes the following:

Condition for hybrid performance: *The transmitted voltages for the even and odd modes must differ from each other by 90 degrees.* This may be restated as

$$L \left( \frac{1}{\lambda_o^e} - \frac{1}{\lambda_o^o} \right) + \phi_r = 1/4, \quad (1)$$

where  $L$  is the length of the coupling section,  $\lambda_o^e$  and  $\lambda_o^o$  are the guide wave lengths for the even and odd modes, respectively, and  $\phi_r$  is the phase shift in the even mode contributed by the reflections from the ends of the coupling section. Two useful additional facts may be inferred also from simple vector arguments concerning the voltages in the even and odd modes. They are:

(a) The output voltages at terminal 1<sub>o</sub> leads the voltage at 2<sub>o</sub> by 90 degrees.

(b) The output voltage at 2<sub>o</sub> leads by 45 degrees what it would be if there were no slot at all in the waveguide.

The first conclusion is a consequence of high isolation, and is independent of the power-division characteristics of the hybrid junction. The second conclusion requires high isolation and the additional assumption that the odd mode does not see the slot.

### SPECIAL THEORY

Since the slot has very little effect on the odd mode, further analysis of the performance of the short-slot hybrid requires a solution of the Maxwell equations which satisfies the boundary conditions for the structure of Fig. 1 excited in the even mode. Fortunately, the solution of this problem is completely known in terms of convergent series, thanks to the work of Carlson and Heins.<sup>11</sup> This results from the fact that the even mode in the coupling section can be expressed in terms of plane waves so that the problem reduces to that of determining the reflection and transmission coefficients for a pair of plane waves suitably incident on an infinite array of metal plates.

The condition for complete isolation requires that the admittance of the structure in both directions as seen from the center of the coupling section shall be real. Accordingly, we determine  $R_o$ , the reflection coefficient, when two in-phase plane waves are incident on a semi-infinite set of metal plates ( $\alpha = \pi/2$ ) along the directions  $\pm \theta$ . Of course  $\theta$  is determined by the requirement that the electric field be zero at the outer wall of the coupling section. In the notation of Carlson and Heins

$$R_o = e^{i(\theta_1 - \theta_2)} \frac{K \cos i - k}{K \cos i + k}. \quad (2)$$

<sup>9</sup> R. H. Dicke, "Principles of Microwave Circuits," M.I.T. Radiation Laboratory Series, McGraw-Hill Book Co., New York, N.Y., vol. 8, pp. 447-448; 1948.

<sup>10</sup> This discussion constitutes a very slight extension of that given by B. A. Lippmann, "Theory of Directional Couplers," M.I.T. Radiation Laboratory Report 860, pp. 33-35; December 28, 1945, and R. L. Kyhl, "Directional Couplers," M.I.T. Radiation Laboratory Series, McGraw-Hill Book Co., New York, N.Y., vol. 11, pp. 889-890; 1947.

<sup>11</sup> J. F. Carlson and A. E. Heins, "The reflection of an electromagnetic plane wave by an infinite set of plates, 1\*, *Quart. Appl. Math.*, vol. 4, no. 4, pp. 313-329; January, 1947.



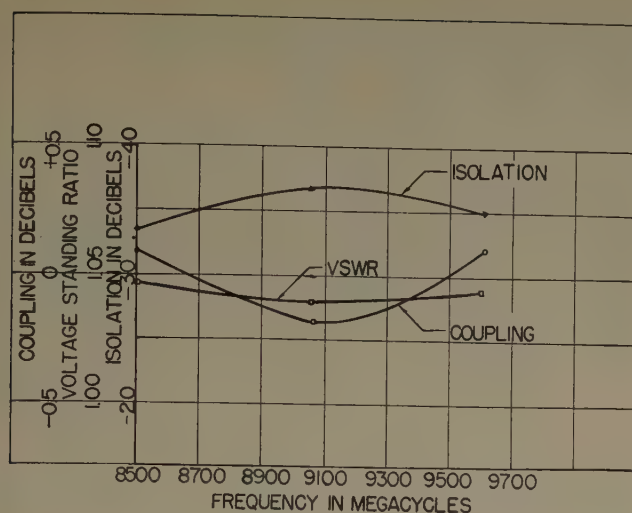


Fig. 5—Best performance.

ficient for our purposes to limit this discussion to two of the most important—namely the balanced mixer and the balanced duplexer. Fig. 6 shows a balanced mixer which uses this type of hybrid junction. Careful examination of the phase relationships shows that the 90-degree phase-shift characteristic of the hybrid junction in no way affects the ability of the mixer to discriminate against local oscillator noise. Pound<sup>12</sup> has gone through this argument in detail and indicated certain advantages for this arrangement in so far as image frequency power is concerned.

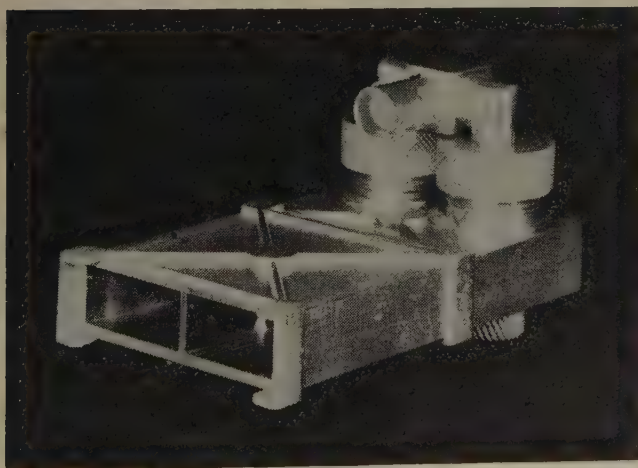


Fig. 6—Balanced mixer.

The principal advantage of the short-slot hybrid for mixer applications results from the close spacing be-

tween crystals which is made possible. Not only does it lend itself to more compact IF amplifier construction using the conventional balanced input transformer design, but it becomes a very simple matter to operate the crystals with a common dc bias. Fig. 6 shows such a mixer.<sup>13</sup> This circuit requires that one of the crystals be inverted with respect to the other. The possible advantages of this circuit over the conventional arrangement using a balanced input transformer appear to be a simpler mechanical arrangement, a perceptible tendency for the rf impedances of the crystal to balance more closely with a common dc bias, and a better over-all noise figure due possibly to the elimination of the closely coupled coils and their inherent losses and unbalances. Unfortunately, the mixer measurements were made with a small number of crystals, so the conclusions regarding noise figure and impedance balance must be considered tentative.

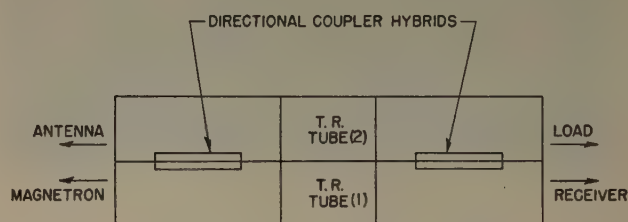


Fig. 7—Schematic balanced duplexer.

Fig. 7 gives a schematic drawing of a balanced duplexer using this type of hybrid. The inherent compactness of this arrangement as compared with the "model city" duplexer described by John Reed is apparent. The 90-degree phase-shift characteristic of the hybrid makes it possible to construct a perfectly symmetrical circuit without a frequency-critical quarter-wave-line length difference. This comes about as follows: Energy from the magnetron splits at the hybrid. The voltage crossing over leads the voltage going straight through by 90 degrees. At the TR tubes, which fire and thus act as short circuits, the energy is reflected without relative phase shift. Voltages in the magnetron branch arising from reflection at TR tube (2) experience an additional 90-degree phase advance, and thus destructively interfere with those which are reflected from TR tube (1). On the other hand, they reinforce in the antenna branch. On reception, the signal level is insufficient to fire the TR tubes, and the energy passes through the second hybrid when it recombines in the receiver branch, with little signal lost in the load.

<sup>12</sup> R. V. Pound, "Microwave Mixers," M.I.T. Radiation Laboratory Series, McGraw-Hill Book Co., New York, N. Y., vol. 16, pp. 277-279; 1948.

<sup>13</sup> The dc series features of this mixer were investigated by the author while employed at the Submarine Signal Co., Boston, Mass. The work was done under a subcontract supported by the Electronics Div., Glenn L. Martin Co., Baltimore, Md.

Fig. 8 is a photograph of a portion of a balanced duplexer which has been designed by the Reeves Instrument Company using these hybrids. One of the short-slot hybrid junctions is shown in the figure together with the two TR tubes and an ingenious mechanism for clamping the tubes in place.

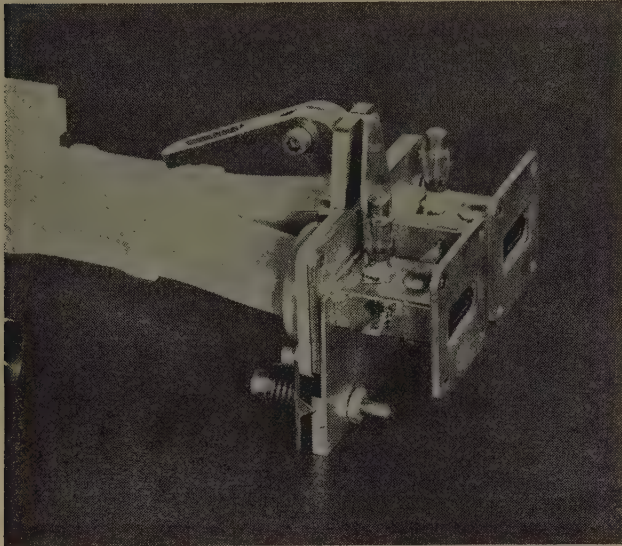


Fig. 8—Balanced duplexer half.

It is clear that the TR tubes may be replaced by shutters to obtain a broad-band mechanical switch or by band-rejection elements in which case one has the elements of a rejection filter. In addition, if the TR tubes are replaced by a pair of ganged movable pistons, a broad-band phase shifter or line stretcher results.<sup>14</sup>

#### ACKNOWLEDGMENTS

I am indebted to Miss Eileen Quigley for the calculation on which the graphs of Figs. 3 and 4 are based. The numerical values were obtained by straightforward summation of the series involved. Dr. Bela Lingyel of the Naval Research Laboratory provided me with unpublished calculations based on very careful summation of these series. Fortunately, the two calculations agree (wherever they overlap) within the accuracy with which the graphs are plotted.

The photograph in Fig. 8 was provided by Mr. John Guarrera of the Reeves Instrument Company.

#### APPENDIX

It is useful to examine qualitatively some of the consequences when the hybrid junctions do not have

perfect performance. The voltages  $B_i$  reflected out of the four terminals when voltages  $A_j$  are incident on them are given by the matrix equation

$$(B_i) = (S_{ij})(A_j),$$

where  $(S_{ij})$  is the scattering matrix of the network. Since the network is lossless, the matrix  $(S_{ij})$  is unitary.<sup>15</sup> This and symmetry imply the following relationships between  $S_{11}$ ,  $S_{12}$ ,  $S_{13}$ , and  $S_{14}$ :

$$\begin{aligned} |S_{11}|^2 + |S_{12}|^2 + |S_{13}|^2 + |S_{14}|^2 &= 1 \\ S_{11}S_{12}^* + S_{12}S_{11}^* + S_{13}S_{14}^* + S_{14}S_{13}^* &= 0 \\ S_{11}S_{13}^* + S_{12}S_{14}^* + S_{13}S_{11}^* + S_{14}S_{12}^* &= 0 \\ S_{11}S_{14}^* + S_{12}S_{13}^* + S_{13}S_{12}^* + S_{14}S_{11}^* &= 0. \end{aligned} \quad (a)$$

From these equations, it may be concluded readily that

$$S_{14} \cdot S_{13}^* - S_{13}S_{14}^* = -2S_{13}S_{14}^* - S_{11}S_{12}^* - S_{12}S_{11}^*, \quad (b)$$

and

$$\begin{aligned} |S_{11}|^2 \{S_{14}S_{13}^* - S_{13}S_{14}^*\} \\ = |S_{12}|^2 \{S_{14}S_{13}^* - S_{13}S_{14}^*\} \\ + \{ |S_{14}|^2 - |S_{13}|^2 \} \{S_{11} \cdot S_{12}^* - S_{12}S_{11}^*\}. \end{aligned} \quad (c)$$

Since  $S_{12}$  is small compared with  $S_{13}$  and  $S_{14}$ , the coefficient of  $|S_{11}|^2$  in (c) cannot vanish. Thus the vanishing of  $S_{12}$  implies that  $S_{11} = 0$ . In words, complete isolation implies perfect match. Moreover, if  $|S_{14}| = |S_{13}|$  we conclude immediately that  $|S_{11}| = |S_{12}|$ . If  $|S_{14}|$  and  $|S_{13}|$  differ by 0.25 db, which is the maximum inequality of output for these hybrids, the  $S_{11}$  will differ from  $S_{12}$  by an error of at most 2.2 per cent. Thus, for all practical purposes, we may immediately infer the maximum SWR from the measurement of isolation. In fact, the isolation measurement can be made with more accuracy than the SWR measurement.

If we write  $S_{ij} = A_j e^{i\phi_j}$ , we may conclude from the second equation of (a) that

$$A_1 A_2 \cos(\phi_1 - \phi_2) = -A_3 A_4 \cos(\phi_3 - \phi_4). \quad (d)$$

Assuming, in the most unfavorable case, that  $\phi_3 = \phi_4$ , we have

$$|\cos(\phi_3 - \phi_4)| \leq \frac{A_1 A_2}{A_3 A_4}.$$

Now the voltage isolation is given by

$$\frac{A_1}{\sqrt{2}A_3} \approx \frac{A_2}{\sqrt{2}A_4}.$$

Hence the isolation immediately determines the maximum amount by which the output phases may differ from 90 degrees. For 20 db of isolation the maximum phase error is of the order of 1 degree; for 30 db of isolation the possible error has dropped to 0.1 degree.

<sup>14</sup> This very interesting application was suggested to the author by Mr. Werner Koppl of the Glenn L. Martin Co.

<sup>15</sup> R. H. Dicke, *ibid.*, pp. 148-149.

# A Statistical Approach to the Measurement of Atmospheric Noise\*

ROBERT S. HOFF†, MEMBER, IRE AND RAYMOND C. JOHNSON‡, ASSOCIATE, IRE

**Summary**—A method of measuring and describing atmospheric noise based on statistical considerations is presented, and apparatus for making the measurement is described. Results obtained are compared on a statistical basis with those obtained by methods of noise measurements in common use. Data obtained at low frequencies are discussed.

## INTRODUCTION

THE PROBLEM of measuring atmospheric noise has been under study at the University of Florida since May, 1946 as a part of a low-frequency noise and wave-propagation investigation sponsored by the Watson Laboratories of the Air Force (Contract W28-099-ac-152). One of the objectives of the program is to establish a correlation between a measure of atmospheric noise and error in matching low-frequency loran pulses. In searching for a measurable characteristic of noise that would serve as a reliable index of its interference effect, the conclusion was reached that measurement of something more definitive than quasi-peak and average values are desirable so that correlations with interference effect can be improved under a wide range of noise conditions. The amplitude-probability-distribution method of measurement presented here was adopted and developed to meet the requirement.<sup>1,2,3</sup>

## ON MEASURING ATMOSPHERIC NOISE

The term "atmospheric noise" is used broadly to define any interfering radio waves generated by electrical disturbances of the atmosphere. According to the currently accepted theory,<sup>4</sup> these disturbing electromagnetic waves originate primarily from lightning flashes, and have energy components throughout the radio-frequency spectrum. Considering the chance occurrence of lightning flashes in time and the variability of flash orientation, current waveform, and conditions over the propagation path, the instantaneous noise voltage in-

duced in a receiving antenna will not depend in any regular way on time as a variable. The same may be said of the envelope of the noise voltage even after the latter has been amplified by a receiver with a restricted pass band and further modified by limiting and other nonlinear processes in the receiver. This random-like voltage envelope appearing at the detector output is the noise voltage, the measurement of which is considered here. As an irregular function of time or time series  $y(t)$ , it may be treated by statistical methods.

Atmospheric noise is generally specified in terms of its average, rms, or quasi-peak value since these parameters can be measured conveniently with conventional equipment. Actually, however, the average and the mean-square values of a sample of noise of duration  $\Delta t$  are simply the first and second statistical moments of the time series for the period.<sup>5</sup> The  $n$ th moment is given by

$$M_n = \int_{-\infty}^{\infty} y^n f(y) dy, \quad (1)$$

where  $M_n$  is the  $n$ th-order moment,  $y$  is the amplitude variable, and  $f(y)$  is the probability density function defining the probability of occurrence of various values of  $y$ . In the form for the moment given, the noise  $y(t)$  is taken as a stationary time series during the period  $\Delta t$ , which makes  $f(y)$  a one-dimension distribution function. Measurements made with equipment to be described later substantiate the assumption that the series is essentially stationary if the period of observation is of the order of one to ten minutes.

To describe a stationary time series by the method of moments, it is necessary to specify not only the first and second moments but the higher order moments as well.<sup>6</sup> The one exception is a density function following the Rayleigh Law, in which case it has been shown that either the first or second moment is sufficient.<sup>7</sup> Unfortunately, practical methods of measuring the higher order moments of atmospheric noise have not been brought to light. As a matter of record, the possibility of describing the noise condition by a measure of its quasi-peak value is even more remote, for such a measure bears no simple relation to a complete statistical description.

The alternate approach is, of course, to consider the direct measurement of the density function. The follow-

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<sup>1</sup> The statistical approach was considered at the suggestion of the late Dr. G. W. Kenrick of the University of Puerto Rico.

<sup>2</sup> K. Maeda and H. Yokoyama, "Automatic Measurement of Atmospheric Noise," Report of Radio Research in Japan, Vol. 7, pp. 153-157; 1937. (Summary only was available to the author.)

<sup>3</sup> H. O. Peterson, "A method of measuring noise levels on short-wave radio-telegraph circuits," *PROC. I.R.E.*, vol. 23, pp. 129-134; February, 1935.

<sup>4</sup> H. A. Thomas and R. E. Burgess, "Survey of Existing Information and Data on Radio Noise over the Frequency Range 1-30 mc/s," Department of Scientific and Industrial Research, Radio Research, Special Report No. 15, H. M. Stationery Office, London, England, pp. 24-25. (Contains a 186-item bibliography.)

<sup>5</sup> "Statistical Theory of Noise," Report No. 102, Research Division, Philco Radio Corp., p. 36.

<sup>6</sup> H. Cramer, "Mathematical Methods of Statistics," Princeton University Press, Princeton, N. J., p. 176; 1947.

<sup>7</sup> "Statistical Theory of Noise," *op. cit.*, pp. 59-60.

ing two probability functions are directly related to the probability density function, and lend themselves to direct measurement.

(a) The probability that the amplitude will fall within the limits  $y_0$  and  $y_0 + \Delta y$  during the time interval  $\Delta t$ , where the probability is given by

$$P(y_0, y_0 + \Delta y) = \int_{y_0}^{y_0 + \Delta y} f(y) dy. \quad (2)$$

(b) The probability that the amplitude will be greater than  $y_0$  during the period  $\Delta t$ , where the probability is given by

$$P(y > y_0) = \int_{y_0}^{\infty} f(y) dy. \quad (3)$$

Of the two forms given, the latter has been chosen, for reasons of circuit simplicity, as the basis for a practical measuring instrument.

### THE MEASURING METHOD AND APPARATUS

Solution of (3) by electrical methods is accomplished by measurement of the per cent-of-time or probability that the noise envelope exceeds a reference level  $y_0$  during the period  $\Delta t$ . To establish the probability during the period for values of  $y_0$  throughout the range of amplitude variation, simultaneous measurements should theoretically be made at a number of reference levels. The period  $\Delta t$  should be sufficiently long so as to encompass a representative cross section of the noise in order to obtain reasonable statistical equilibrium and associated statistical significance. Practically, a  $\Delta t$  of the order of seconds is used, and measurements at the various reference levels are made consecutively, with from one to ten minutes being spent at each level to insure that a representative reading has been obtained. The result is a record of the time variation of probability of a sample of noise examined during the previous  $\Delta t$  seconds as the period advances in time. Measurement of probability at each level in turn introduces no error only if the function  $f(y)$  does not change during the complete measuring cycle. Experience shows that the curves change slowly with time, except during sudden thunderstorms, sunrise, and sunset. It is noted here that more complex apparatus for making measurements simultaneously at all levels is a straightforward design problem, and would undoubtedly contribute to the accuracy of measurements during periods of rapidly changing noise conditions.

Operation of the practical measuring apparatus, shown in block-schematic form in Fig. 1, is based on the consideration that the average value over a period  $\Delta t$  of a series of rectangular pulses of equal amplitude, the width and spacing of which are determined by chance, is proportional to the per cent-of-time in which pulses occurred. This consideration is related to the per cent-of-time that a noise-envelope voltage exceeds a particular reference level by causing a current of fixed value to be

interrupted suddenly whenever the reference level is exceeded, thus forming pulses which can be averaged as outlined above. The time constant of an RC network establishes the period  $\Delta t$  over which pulses are averaged. Per cent-of-time, in this case, is probability as it applies to past events.

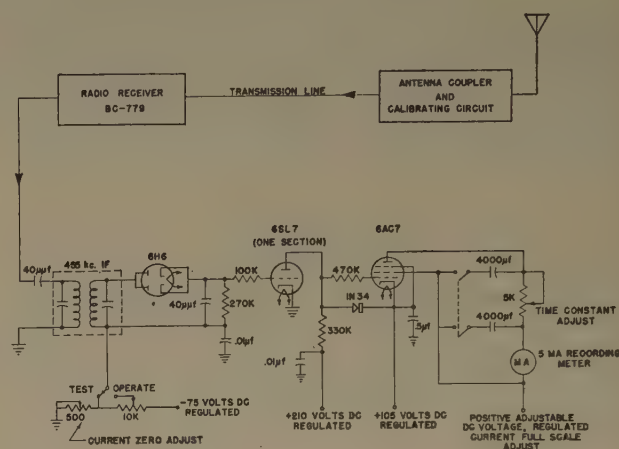


Fig. 1—Functional diagram of measuring system.

A dummy antenna capacitor is included in the antenna coupling unit for calibration of the system at any frequency in the range 100 to 400 kc. Operation of the receiver on the linear portion of its input-output characteristic is insured by using a step attenuator in the antenna circuit. Errors arising from the use of automatic gain control are thereby eliminated.<sup>8</sup>

In the measurement section of the system, current pulses are formed in the plate circuit of the 6AC7 tube by the action of the crystal diode and a series grid resistor. Adjustment is accomplished by setting the *current-zero adjust* resistor to maximum with the *test-operate* switch in the *test* position, adjusting the *current full-scale adjust* control for a 5-ma deflection of the recording meter and then resetting the *current-zero adjust* control for zero current in the recording meter.

Accuracy and operating flexibility of the system described can be improved by providing more gain following the diode detector, by the addition of an automatic attenuator and bias-level switching system, by providing for an up-scale reading meter and by incorporating a servosystem for automatic setting of the bias level when recording on a constant-percentage basis is desired. Many of these improvements are being considered for inclusion in improved models.

### PRESENTATION AND INTERPRETATION OF DATA

Raw data produced by the instrument described can be presented in their most fundamental form as a probability distribution curve for each period over which a cycle of measurement was made. Fig. 2 shows a typical sample of a recorder chart containing three cycles of measurement. Examples of plotted data are given in

<sup>8</sup> H. E. Dinger and H. G. Paine, "Factors affecting the accuracy of radio noise meters," *Proc. I.R.E.*, vol. 35, pp. 75-81; January, 1947.

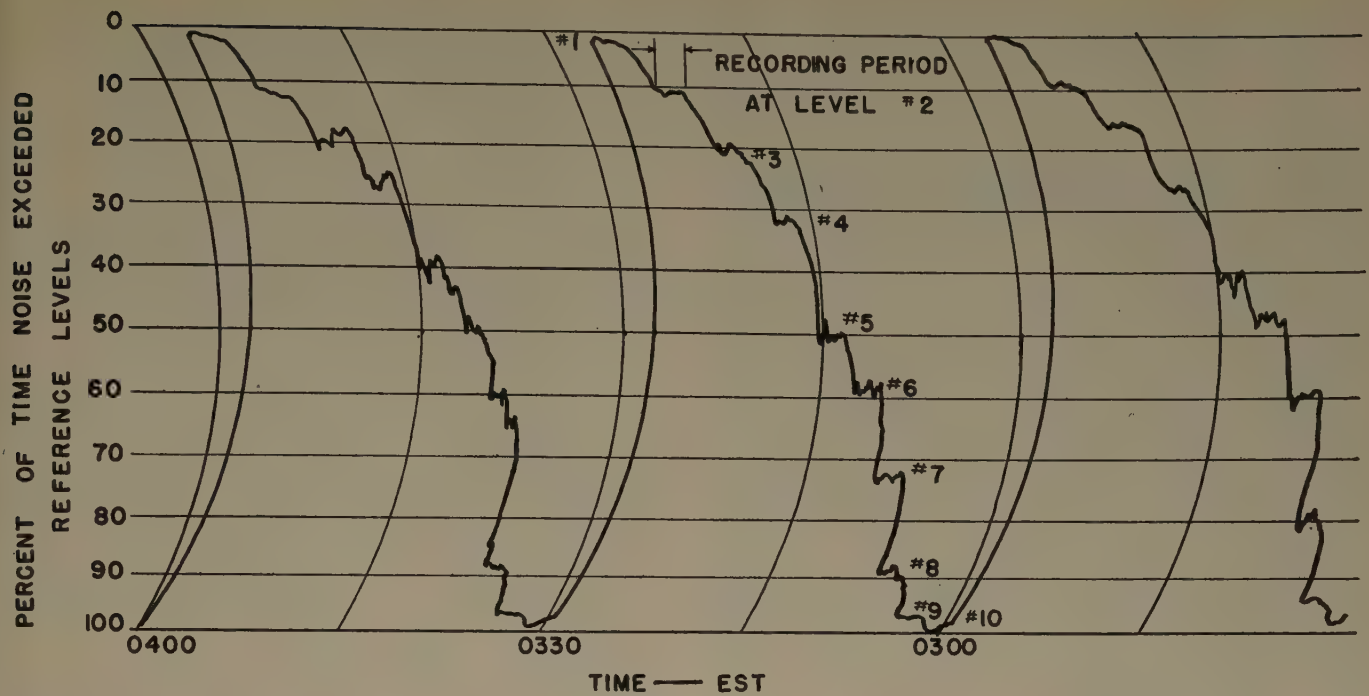


Fig. 2—Typical sample of recorder chart.

Fig. 3 for fluctuation noise and for atmospheric noise at three different times. All have been normalized to reduce the effect of general noise-amplitude level changes. The fluctuation noise curve follows the integral of the Rayleigh distribution closely, and provides a check on the proper operation of the system. Differences in the curves for atmospheric noise clearly point up the variations which may be expected.

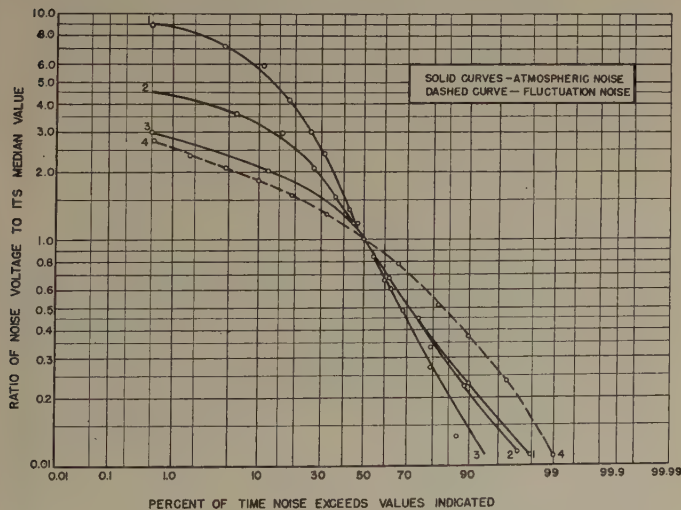


Fig. 3—Distribution curves of atmospheric and fluctuation noise.

Admittedly this and other obvious graphical presentations of the statistical measures of noise are time consuming to prepare and test for correlation with the interference effect of the noise. This problem is recognized, and efforts are being made to develop a mathematical expression that will fit the measured curves. In any case, the graphical presentations should serve as a basis for determining just which characteristics of

noise play the major part in interfering with particular radio services whenever the interference effect can be evaluated on a quantitative basis.

### CONCLUSIONS

The primary purpose of this report has been to point out the basic shortcomings of the conventional methods of measuring atmospheric noise and to present a more fundamental statistical method of measurement which shows promise of giving a much more accurate description of the noise condition. The amplitude-probability-distribution measurement provides this improved description, and should, therefore, prove to be a useful tool for the investigation of noise-interference effect and for the study of the thunderstorms from which atmospheric noise originates.

As for the apparatus described, it served the special purpose of demonstrating the practicability of the statistical measurement and furnished quantitative information as to the nature of and variations in the statistical characteristics of atmospheric noise at low frequencies. The operating principle is applicable to any probability distribution measuring problem in which data, either smooth or with discrete values, can be converted into a voltage with a corresponding amplitude variation.

There is ample evidence to show that objective atmospheric-noise measurements made in the past have not been used in communication-system planning without the application of a large factor of safety to compensate for the inadequacies of the noise data available. It is hoped, therefore, that the information presented here will provide the means whereby the interference effect of noise may be more accurately assessed and taken into account.

# Shorted Stubs of High Resonant Impedance\*

JOSEPH M. DIAMOND†, ASSOCIATE, IRE

**Summary**—Curves are developed which specify the parameters of a coaxial or twin-line shorted stub of maximum resonant impedance when the frequency, outer dimension, and lumped capacitance at the open end are given.

WE ARE CONCERNED with obtaining the maximum resonant impedance from a shorted length of coaxial or twin transmission line when the open end is loaded with lumped capacitance. Thus the line will be less than a quarter wavelength long. The quantity held constant will be the outside diameter for the coaxial line and the center-center spacing for the twin line.

When the lumped capacitance is zero, a quarter wavelength line is required; the optimum dimensions of this line for maximum impedance have been derived by Terman.<sup>1</sup> However, it is often impossible to avoid some lumped capacitance at the open end (if, for example, capacitive tuning is desired). The present investigation was, in fact, prompted by the necessity of obtaining a high-impedance tuned circuit at 400 mc for the measurement of high resistance by the susceptance-variation method. The curves presented here allow a line of maximum impedance to be calculated when the lumped capacitive reactance and outside line dimensions are given.

The curves are based on an extension of a paper by Nergaard and Salzberg,<sup>2</sup> who develop the following equation for resonant impedance from the fundamental transmission-line equations:

$$r = \frac{Z_0}{k} \left( \frac{1 - \cos 2\theta}{2\theta + \sin 2\theta} \right), \quad (1)$$

where

$r$  = resonant impedance

$Z_0$  = characteristic impedance

$\theta$  = line length (degrees)

$k = R_0/2\omega L_0$

$R_0$  = line resistance per unit length

$L_0$  = line inductance per unit length

$\omega$  = angular frequency

$C$  = lumped capacitance at open end.

To produce resonance the following condition must be satisfied:

$$\omega CZ_0 = \cot \theta. \quad (2)$$

Thus, if the line constants were known, the required  $\theta$  and resulting  $r$  could be found. Since  $R_0$  (including skin effect) and  $L_0$  depend upon line dimensions, the design problem is more involved. The relations given below in Table I are well known.

TABLE I

Coaxial Line	Twin Line
$Z_0 = 138 \log b/a$ ohms	$276 \log d/a$ ohms
$L_0 = 4.60(10^{-7}) \log b/a$ henries per meter	$9.21(10^{-7}) \log d/a$ henries/meter
$R_0 = 4.16(10^{-8}) \sqrt{f}(1/a - 1/b)$ ohms per meter (for copper)	$8.33(10^{-8}) \sqrt{f}/a$ ohms/meter (for copper)
$a$ = inner radius (cm)	$a$ = conductor radius (cm)
$b$ = outer radius (cm)	$d$ = center-center spacing (cm)
$f$ = frequency in cps all logs to base 10	

Combining these equations with (1) and (2), we obtain

$$\text{Coaxial} \quad \frac{r}{b\sqrt{F}} = \frac{219X_c^2}{1 + 10^{X_c/138 \tan \theta}} \cdot \phi(\theta) \quad (3)$$

$$\text{Twin} \quad \frac{r}{d\sqrt{F}} = \frac{100X_c^2}{10^{X_c/276 \tan \theta}} \cdot \phi(\theta), \quad (4)$$

where

$$\begin{aligned} \phi(\theta) &= \frac{0.458}{\tan^2 \theta} \left( \frac{1 - \cos 2\theta}{2\theta + \sin 2\theta} \right) \\ &= 0.458 \left( \frac{1 + \cos 2\theta}{2\theta + \sin 2\theta} \right) \end{aligned} \quad (5)$$

$$X_c = \frac{1}{\omega C}$$

$F$  = frequency in hundreds of mc.

Equations (3) and (4) give the resonant impedance obtained with a given  $X_c$ ,  $F$ , outside line dimension, and  $\theta$ , when  $Z_0$  is adjusted to produce resonance. The equations are plotted in Figs. 1 and 2 as functions of  $\theta$ , with  $X_c$  as parameter. For a given  $X_c$ , the peak of the curve shows that there is an optimum value of  $\theta$ . The corresponding  $Z_0$  is given by (2). Fig. 3 shows the optimum impedance obtained as a function of  $X_c$ , as well as the optimum values of  $\theta$  and  $Z_0$ ; these curves were obtained from the peak points of Figs. 1 and 2. As  $X_c$  becomes infinite, the values approach those given by Terman for the optimum self-resonant 90-degree line.

If the conductor is other than copper, the impedance obtained will be proportional to the square root of the conductivity, but otherwise all curves apply. Radiation, dielectric, and shielding losses are not included in this analysis. Thus, better agreement with calculated re-

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<sup>1</sup> For the original paper, see F. E. Terman, "Radio Engineers' Handbook," p. 191; also, F. E. Terman, "Resonant lines in radio circuits," *Trans. AIEE*, vol. 53, p. 1046.

<sup>2</sup> Nergaard and Salzberg, "Resonant impedance of transmission lines," *PROC. I.R.E.*, vol. 27, p. 579.

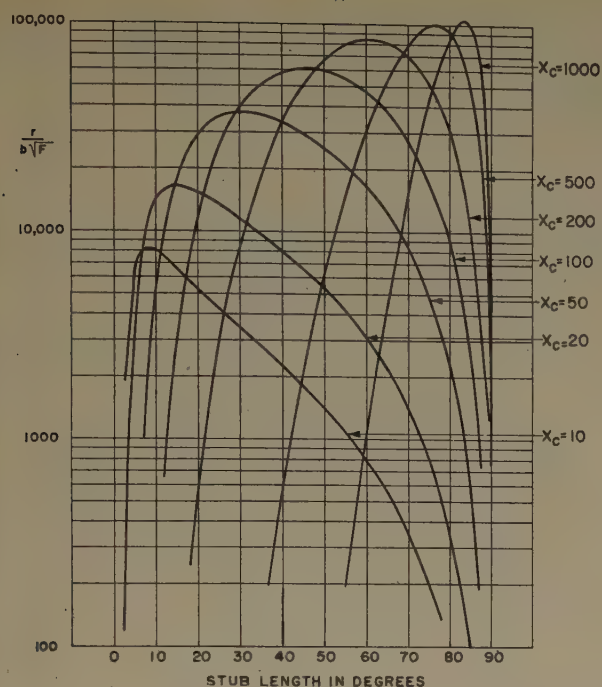


Fig. 1—Resonant impedance of a shorted coaxial stub. For resonance,  $Z_0 = X_c / \tan \theta$   
 $b$  = Outer radius in cm  
 $F$  = Frequency in hundreds of mc  
 $r$  = Resonant impedance in ohms  
 $X_c$  = Lumped capacitive reactance at open end

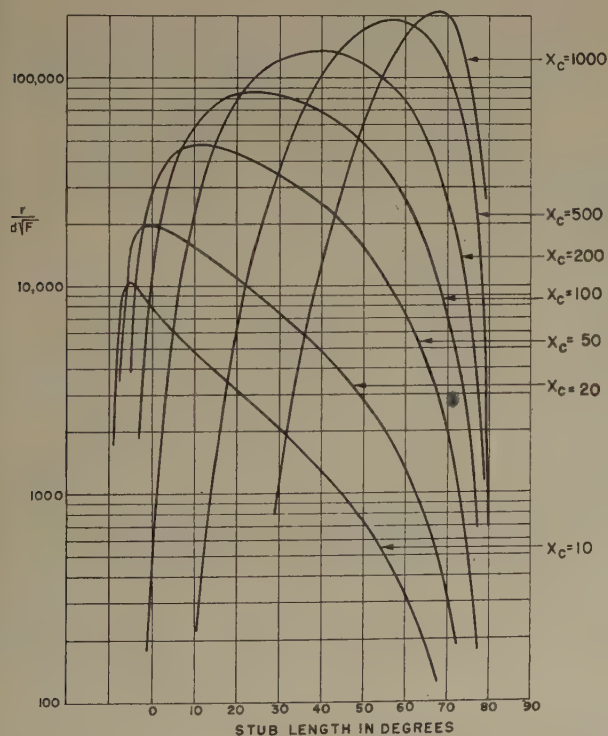


Fig. 2—Resonant impedance of a shorted twin-line stub. For resonance,  $Z_0 = X_c / \tan \theta$   
 $d$  = Spacing in cm  
 $F$  = Frequency in hundreds of mc  
 $r$  = Resonant impedance in ohms  
 $X_c$  = Lumped capacitive reactance at open end

sults can be expected for the coaxial line, which is self-shielding, than for the twin line, which is affected by surrounding materials.

For example, a high-impedance coaxial stub is desired at 200 mc; the inner diameter of the outer conductor = 2 inches and the lumped capacitance = 10  $\mu\text{mf}$ . We have, therefore,  $F = 2$ ,  $b = 2.54$  cm and  $X_c = 79.6$  ohms. Fig. 3 gives the parameters of the optimum line as  $Z_0 = 97$  ohms,  $\theta = 39$  degrees, and  $r/b\sqrt{F} = 53$  kilohms. Therefore, the diameter of the inner conductor =  $2/10^{97/188} = 0.396$  inches, the stub length =  $(39/360)(300/200) = 6.40$  inches, and the resonant impedance =  $(53,000)(2.54)\sqrt{2} = 190,000$  ohms. These dimensions are not critical, however. The following table shows the impedance obtained and stub length requires when the inner conductor diameter is varied from  $\frac{1}{4}$  to  $\frac{3}{4}$  of an inch. Since it is difficult to interpolate between the curves of Figs. 1 and 2 in the neighborhood of the maxima, the values in Table II were calculated from (2) and (3):

TABLE II

Diameter of inner conductor, inches	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$
Stub length required, inches	5.32	6.32	7.19	7.98	8.80
Resonant impedance, kilohms	177	190	190	176	154

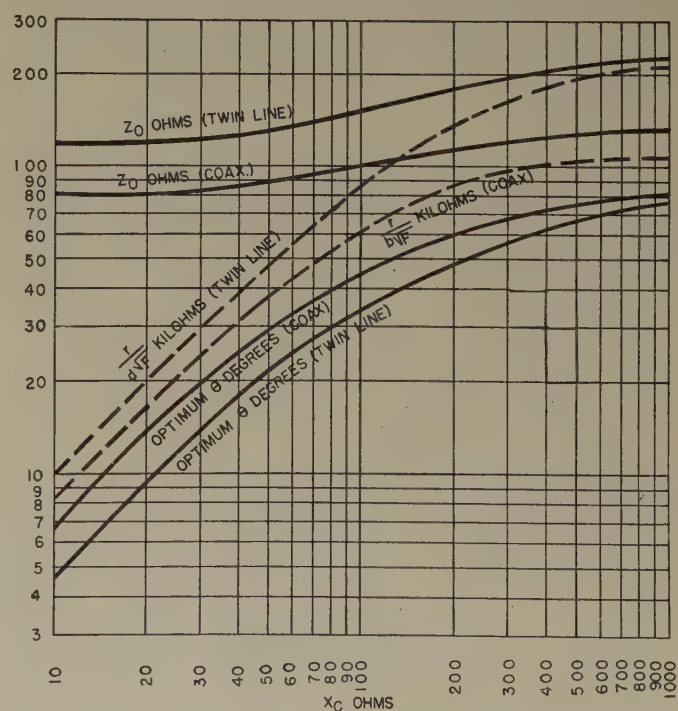


Fig. 3—Parameters and performance of the optimum line as a function of  $X_c$ .

# The Influence of the Core Material on the Thermionic Emission of Oxide Cathodes\*

H. A. POEHLER†, ASSOCIATE, IRE

**Summary**—The influence of the core material on the thermionic emission of oxide cathodes was investigated. Alloys of nickel with 4.8 per cent Mn, 4.0 per cent Al, 0.38 per cent Mg, and 3.5 per cent W were used as cores, with pure electrolytic nickel as a core being used as a control. The experiments showed that both the dc and pulsed emission of oxide cathodes are dependent on the core to a marked degree.

## INTRODUCTION

THE EFFECT of the core material on the thermionic emission of oxide cathodes was early discounted by the work of Deininger.<sup>1</sup> Lowry<sup>2</sup> and Beese<sup>3</sup> reopened the question in the 1930's, and Benjamin<sup>4</sup> contributed to it in 1935. Since 1939, however, the problem of the influence of the core material has received increasing attention.<sup>5-12</sup>

To date, the only work on the effect of the more common impurities found in commercial, cathode-type nickel on the thermionic emission of nickel-base oxide cathodes is that of Benjamin.<sup>4</sup>

Among other materials, the effect of which was studied by Benjamin, were 0.07-per cent Mg-, 0.34-per cent Mn-, and 2-per cent Al-nickel alloys, used as core material for oxide cathodes. His work, however, is open to several criticisms. The most serious of these is his measurement of saturation currents at such high temperatures as 1,020° K under dc conditions. Such measurements are subject to the following errors:

- (a) Poisoning by evolution of gases from the anode.
- (b) Poisoning by evolution of gases produced by the decomposition of anode deposits.<sup>13,14</sup>
- (c) Heating of the coating by the  $I^2R$  loss in the coating itself, caused by the resistance of the coating. This is a serious criticism of Benjamin's work since he made the assumption that the "brightness temperature would depend only on the watts supplied to the filament." Thus, it is difficult to say what part of the differences in emission noted by Benjamin were due to, or were masked by, differences in  $I^2R$  loss in the coating.

Moreover, the use of two cathodes in one envelope is open to question because of the possibilities of affecting the emission of one cathode by the gases given off by the other cathode.

## DISCUSSION OF METHODS

### A. Vacuum Systems

The system was pumped with a three-stage, glass-fractionation pump, using Octoil-S. The vacuum was measured with a distillation products, VG-1A ionization tube. A trap was located between the diffusion pump and the manifold. This trap was baked to 400° C each time the manifold was baked to 450° C. With this system, the pressure as measured at the gauge was consistently lower than  $1 \times 10^{-7}$  mm Hg, and generally  $6 \times 10^{-8}$  mm at tipoff.

### B. Description of the Tube

The tube used in these experiments was the "Coomes Diode,"<sup>15</sup> which was developed by the Radiation Laboratory at M.I.T. The tube is illustrated in Fig. 1. The anode and leads are made of kovar. The tube is so designed as to permit the anode to be water cooled. The anode can then be operated at low temperatures, even for a relatively high anode dissipation. The design is also such as to allow the tube to be sealed with a minimum oxidation of the tube parts.

In order to measure cathode temperatures below 800° C, a thermocouple was added to the tube. The

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† General Precision Laboratory, Inc., Pleasantville, N. Y.

<sup>1</sup> F. Deininger, "On the emission of oxides," *Ann. Phys. (Lpz)*, vol. 25, p. 285; 1908.

<sup>2</sup> E. Lowry, "The role of core metal in oxide cathodes," *Phys. Rev.*, vol. 35, p. 1367; 1930.

<sup>3</sup> N. Beese, "Ba-Ni alloy core for oxide cathodes," *Phys. Rev.*, vol. 36, p. 1309; 1930.

<sup>4</sup> M. Benjamin, "The influence of metallic impurities in the core of oxide cathodes," *Phil. Mag.*, vol. 20, p. 1; 1935.

<sup>5</sup> W. Liebold, "Dissertation," University of Berlin, Berlin, Germany; 1941.

<sup>6</sup> A. Fineman and A. Eisenstein, "Studies of the interface of oxide cathodes," *Jour. Appl. Phys.*, vol. 17, p. 663; August, 1946.

<sup>7</sup> H. Jacobs and G. Hees, "Variations in the constants of Richardson's equation as a function of life for the case of oxide coated cathodes on nickel," *Phys. Rev.*, vol. 72, p. 174; July, 1947.

<sup>8</sup> W. Mutter, "Rectification characteristics of an oxide cathode interface," *Phys. Rev.*, vol. 72, p. 531; September, 1947.

<sup>9</sup> D. Wright, "Oxide cathodes, the effect of coating-core interface on conductivity and emission," *Proc. Roy. Soc. A*, vol. 190, p. 394; 1947.

<sup>10</sup> J. Acker, "A.S.T.M. committee work—factory tests on cathode Ni," *Proc. I.R.E.*, vol. 36, p. 376; March, 1948.

<sup>11</sup> H. Jacobs, G. Hees, and W. Crossley, "Thermionic emission of oxide coated filaments," *Bull. Amer. Phys. Soc.*, vol. 23, p. 12; 1948.

<sup>12</sup> R. McCormack, "A standard diode for radio-tube-cathode core material approval tests," *Proc. I.R.E.*, vol. 36, p. 376; March, 1948.

<sup>13</sup> H. Jacobs, "Dissociation energies of surface films of various oxides as determined by emission measurements of oxide cathodes," *Phys. Rev.*, vol. 69, p. 692; 1946. Also, *Jour. Appl. Phys.*, vol. 17, p. 596; July, 1946.

<sup>14</sup> H. Bruining, H. Hamaker, and A. Alten, Jr., "On the activation of oxide cathodes," *Philips Res. Rep.*, vol. 2, p. 171; 1947.

<sup>15</sup> E. Coomes, J. Buck, A. Eisenstein, and A. Fineman, "Alkaline Earth Oxide Cathodes for Pulsed Tubes," N.D.R.C., Div. 14, OEMsr 262, Report 933; March 30, 1946. (Publ. No. PB 55739, Office of Technical Services, U. S. Dept. of Commerce.)

couple was composed of an extremely fine, 0.002-inch diameter molybdenum wire, which was welded onto the cathode sleeve immediately adjacent to the coating.

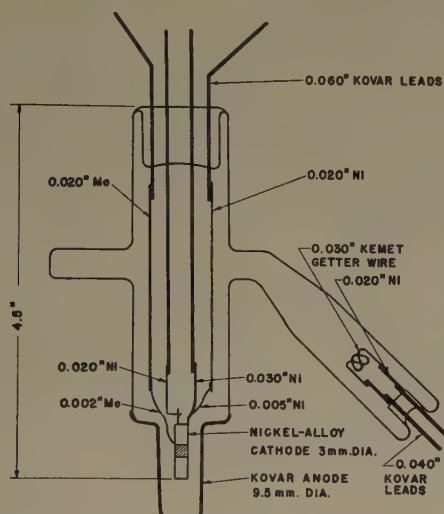


Fig. 1.—Diode construction.

To minimize end effects, only the center 4 mm of the 14-mm long cathode were coated. Before tipoff, all tubes were gettered by flashing an iron-clad barium getter, which had been carefully degassed before cathode activation.

### C. Techniques and Processing

The utmost attention was paid to the adherence of a uniform processing technique for all the tubes. The processing techniques<sup>15</sup> developed by the M.I.T. Radiation Laboratory were taken as the basis for this work, with the following exceptions: Al-, Mg-, and Mn-nickel-alloy cathodes were only vacuum fired, not hydrogen fired; Mn-nickel alloy cathodes were vacuum flashed at 950° C instead of 1,000° C because of the volatility of the manganese; and all the tubes were continuously flushed with dry nitrogen during sealing to minimize oxidation of the leads.

The salient points of the processing technique may be briefly enumerated. The kovar anode is outgassed by electron bombardment at 1,500 volts from a dummy tungsten filament. The central portion of the anode is heated to 800° C (brightness temperature) until the pressure is  $5 \times 10^{-7}$  mm. The cathodes are vacuum fired in a separate envelope. Each is flashed at 1,000° C for 5 minutes, and held at 850° C until the pressure is  $2 \times 10^{-7}$  mm. The fired cathodes are sprayed with an equimolecular mixture of barium and strontium carbonates in a nitrocellulose binder to a controlled coating weight of from 9 to 12 mg/cm.<sup>2</sup> When the sprayed cathodes are ready for mounting, the diodes are carefully opened with a hot wire and the sprayed cathode is

mounted in place of the tungsten filament that was used to bombard the anode. The technique is such that the processed parts are exposed to the air only for the irreducible time necessary for spraying, mounting, and sealing.

### D. Emission Measurement

The most direct method of approach is to use direct-current measurements at the normal operating temperatures of from 700 to 900° C, and to increase the plate voltage until the plate current begins to saturate. To consider this current as the temperature-limited emission of the cathode for that temperature, and hence as a measure of the cathode emission, is a serious error.

The primary faults are the following:

1. *The Anode Effect*—It is extremely difficult, if not impossible, to construct and sufficiently outgas an anode so that it will not liberate gases when saturation currents are drawn from the cathode. This is primarily because the saturation currents of oxide cathodes are so high and oxide cathodes are readily poisoned by minute amounts of gases that will react with free barium.

2. *I<sup>2</sup>R Heating and Coating Changes*—In drawing currents in the neighborhood of saturation, the  $I^2R$  loss in the coating itself becomes comparable to the heater input.

For these reasons, in order to measure reliably the cathode-emission ability, it is necessary to take measurements at much reduced temperatures and currents, i.e., at from 150 to 400° C,  $10^{-10}$ – $10^{-6}$  a/cm.<sup>2</sup>. Under these conditions the anode dissipation, and hence the gas liberation from the anode, is kept at an absolute minimum; furthermore, the passage of current through the cathode is kept exceedingly small so as to cause a minimum of disturbance to the existing physico-chemical makeup of the cathode.

In an effort to overcome the anode limitation, efforts were made as early as 1930 by Thomson,<sup>16</sup> and later by Maddock,<sup>17</sup> Heinze,<sup>18</sup> and Patai,<sup>19</sup> to draw emission current in pulses. In this manner, high peak currents could be drawn at operating temperatures of from 700 to 900° C at low anode temperatures, and hence at low poisoning levels. Thomson was able to reach peak currents as high as 3a/cm.<sup>2</sup> in this manner.

Within recent years, by use of microsecond pulses, it was found that oxide cathodes could deliver up to 100 a/cm.<sup>2</sup>, space-charge limited,<sup>15,20</sup> and up to 150 a/cm.<sup>2</sup>,

<sup>16</sup> B. Thomson, "High efficiency emission from oxide-coated filaments," *Phys. Rev.*, vol. 36, p. 1415; 1930.

<sup>17</sup> A. Maddock, "Activation of oxide cathodes," *Phil. Mag.*, vol. 19, p. 422; 1935.

<sup>18</sup> W. Heinze, "Calorimetric determination of work function for oxide cathodes," *Ann. Phys. (Lpz)*, vol. 16, p. 41; 1933.

<sup>19</sup> E. Patai and G. Frank, "Emission constants of oxide cathodes," *Z. techn. Phys.*, vol. 16, p. 254; 1935.

<sup>20</sup> E. Coomes, "Pulsed properties of oxide cathodes," *Jour. Appl. Phys.*, vol. 17, p. 647; August, 1946.

space-charge limited,<sup>21,22</sup> when an auxiliary dc current was simultaneously drawn.

Our emission measurements were made by measurement at low temperatures and low current drain, and by pulse testing at 1 microsecond and at a low repetition rate, such as 60 cycles.

In addition to the gases given off from the anode as a result of excessive heating, it has been shown, by Jacobs<sup>13</sup> and Bruining,<sup>14</sup> that cathodes may be poisoned by the dissociation of oxide deposits on the anode. Where cathodes contain appreciable quantities of impurities, for example, magnesium, silicon, manganese, and the like, we may also expect to find their oxides on the anode. These compounds will be decomposed, as Jacobs has shown, at critical potentials, corresponding to the heats of formation. If the anode voltages are kept below this level, no dissociation of the anode deposit occurs, and hence there is no gas liberation and consequent emission decay.

For this reason the anode potentials on all the dc, low-temperature measurements have been restricted below 6 volts. Since a contact potential of at least 1 volt is generally present, in effect, only 5 volts remain to produce dissociation. This potential is below that corresponding to the critical potentials for any of the compounds likely to be deposited on the anode. Proof of this statement is the fact that in our measurements, up to 6 volts, absolutely no emission decay could be noted.

1. *Low-Temperature, dc Measurements:* Currents in the range of  $10^{-6}$ – $10^{-11}$  amperes were measured with a dc amplifier, and cathode temperatures below 700° C were measured by means of a thermocouple, formed by spot welding 0.002-inch molybdenum wire to the cathode immediately adjacent to the coating.

2. *Pulsed Measurements:* The pulsed measurements were made with a standard, Link Model-4 modulator, which was triggered at 60 cycles by a standard P4 Browning synchroscope.

The emission current was determined by measuring the drop of potential across a noninductive resistor, and the potential was measured by means of a capacity potential divider.

### E. Calibration

For the cathode-thermocouple calibration, special vacuum tubes, 2 feet in length, were constructed so that the one end containing the cathode could be kept in an oven, while the other end could be maintained at a fixed temperature. The temperature in the oven was measured by a chromel-alumel thermocouple immediately adjacent to the outside of the 2-foot tube and at the

level of the cathode. The chromel-alumel thermocouple, in turn, was calibrated against three fixed points: the boiling point of water, the melting point of tin, and the melting point of zinc.

## RESULTS

By measuring the dc emission at low temperatures and at low current levels, and by measuring pulsed emission at normal operating temperatures, significant differences in emission, which can be attributed to the core,<sup>23</sup> were found. The results are tabulated in Table I.

TABLE I  
TABULATED RESULTS

Core	Tube No.	Zero-Field Current at 230° C $\times 10^{-9}$ a/cm <sup>2</sup>	Sparking Current at 880° C a/cm <sup>2</sup>
3.5% W-Ni alloy	38	385	51
	27	395	40
	25	520	52
	73	525	61
		460 ± 66*	
Electrolytic nickel	56	195	31
	31	245	37
	51	250	38
	66	240	45
		230 ± 22	
0.38% Mg-Ni alloy	37	46	28
	33	57	—
	48	79	35
	70	78	26
		65 ± 14	
4.0% Al-Ni alloy	35	42	27
	36	26	—
	58	42	23
		37 ± 7	
4.8% Mn-Ni alloy	26	1.8	14
	67	1.4	11
	34	8.0	19
	71	4.1	22
		4 ± 3	
		17 ± 4	

\* Standard deviation.

The dc, low-temperature emission readings were taken in the range from 150 to 400° C and  $10^{-10}$ – $10^{-6}$  a/cm<sup>2</sup>. A typical set of data, illustrating the effect of the core material, is shown in Fig. 2. Tubes #73 and #34 are identical in every respect, except the core material. At a 10-degree higher temperature, however, the emission of the 4.8-per cent Mn-Ni cathode is only one-hundredth that of the 3.5-per cent W-Ni alloy.

To obtain the zero-field currents tabulated in Table I, the saturation currents were extrapolated to zero-field by the use of the Schottky equation,<sup>24</sup>  $\log I/I_0 = K/T\sqrt{E}$  where  $I$  is the saturation current at the anode potential  $E$ ,  $I_0$  is the saturation current when the field at the

<sup>23</sup> Chemical analysis of the cores is given in Tables II and III, Appendix.

<sup>24</sup> W. Schottky, "Ueber den Einfluss der Bildkraefte," *Phys. Z.*, vol. 15, p. 872; 1914.

The Schottky equation is derived from, and strictly applies only to, the emission of homogeneous metal surfaces. It is used for composite emitters, such as oxide cathodes, in lieu of an equation strictly applicable to composite cathodes. When so used, it is found that the slope is different from that given by the Schottky equation.

<sup>21</sup> W. Ramsey, "Sparking of Oxide Cathodes," N.D.R.C., Div. 14, OEMsr 358, Report 294; July 15, 1944. (Publ. No. PB12136, Office of Technical Services, U. S. Dept. of Commerce.)

<sup>22</sup> W. Ramsey, "General Survey of Sparking in H. V. Thermionic Tubes," N.D.R.C., Div. 14, OEMsr 358, Report 516, Oct. 31, 1945, 91p PB12128. Office of Technical Services, U. S. Dept. of Commerce.

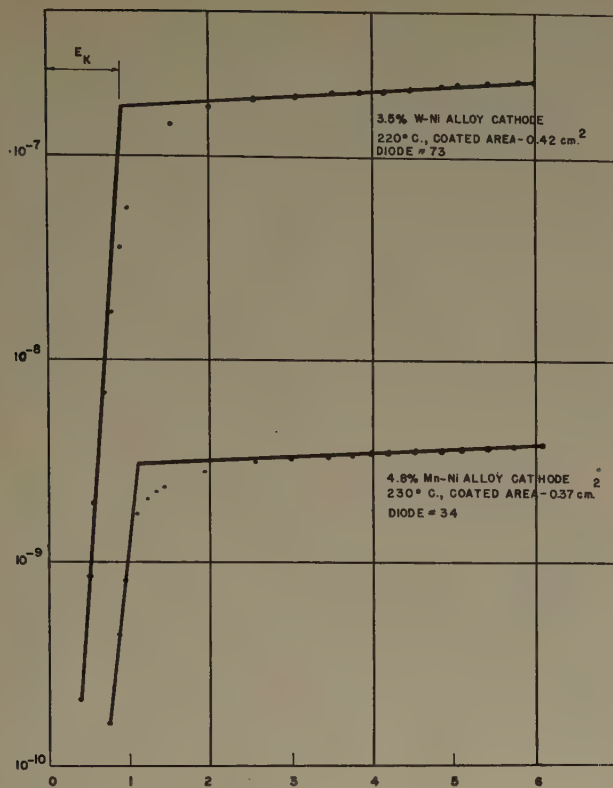


Fig. 2—Effect of the core material on the dc-emission characteristics of diodes at low temperatures. Ordinate is current in amperes; abscissa is applied anode potential in volts.  $E_K$  is the contact potential.

cathode is zero,  $T$  is the temperature, and  $K$  is a constant. Fig. 3 shows the extrapolation of the saturation

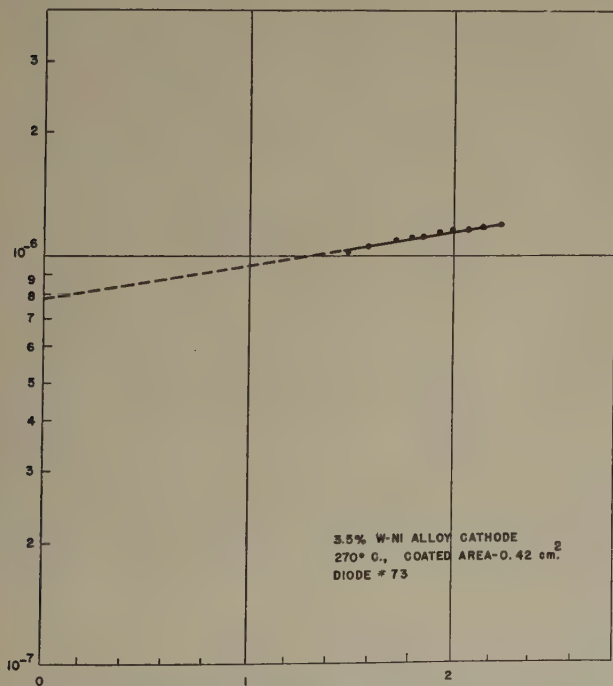


Fig. 3—Determination of the zero-field emission current extrapolation from the Schottky  $\sqrt{E}$  characteristic. Ordinate is current in amperes. Abscissa is  $\sqrt{E_A - E_K}$ , where  $E_A$  is the applied anode potential and  $E_K$  is the contact potential; unit is  $\sqrt{\text{volts}}$ .

currents to zero-field, using the Schottky relation. Account has been taken here of the contact potential, which must be added algebraically to the applied voltage to obtain the voltage that appears in Schottky's relation. The contact potential is given to a sufficient degree of accuracy by the intersection<sup>25,26</sup> of the initial and the saturation-current lines (Fig. 2).

The saturation currents for each cathode were measured for at least three different temperatures. The zero-field currents were determined, and were plotted against temperature. A typical set of data is shown in Fig. 4.

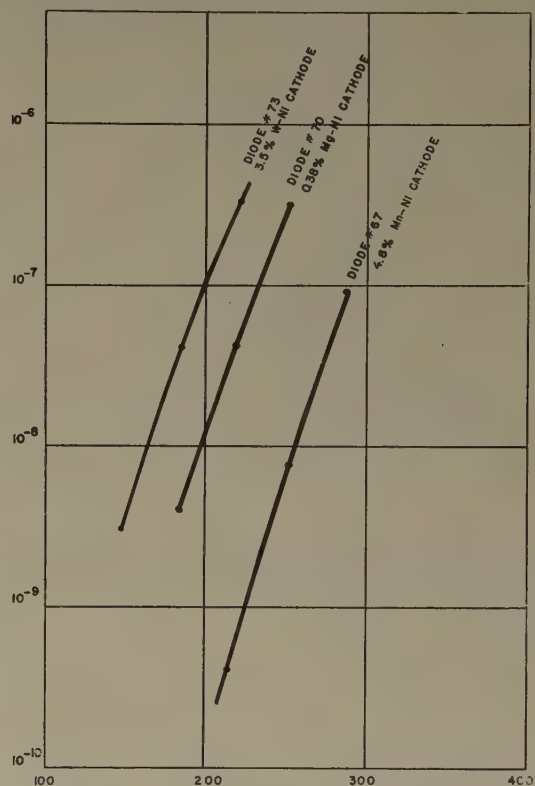


Fig. 4—Effect of the core material on the emission current of oxide cathodes. Ordinate is zero-field emission current in amperes per square centimeter; abscissa is temperature in degrees centigrade.

The comparative zero-field emission currents, shown in Table I, were taken from these graphs at the arbitrary temperature of 230° C. As noted earlier, the tubes were seasoned on the pumps. The emission measurements were made shortly after the tubes were taken off the vacuum system. The dc test was made first, the tubes being aged 10 minutes at 850° C (brightness) and 250 ma/cm<sup>2</sup> before the test. The tubes were retested after one hour dc operation at 850° C (brightness) and 250 ma/cm<sup>2</sup>, with satisfactory agreement.

The sparking currents are significant because they limit the maximum current that can be drawn from a cathode. There is evidence<sup>15,21,22</sup> that sparking is initiated by a metallic vapor, but whether this vapor is

<sup>25</sup> H. Rothe, "Austrittsarbeit und Kontaktpotential," *Z. techn. Phys.*, vol. 6, p. 633; 1925.

<sup>26</sup> W. Heinze and S. Wagener, "Variations of emission constants of oxide cathodes during activation," *Z. Phys.*, vol. 110, p. 164; 1938.

produced by a dielectric breakdown or by an  $I^2R$  heating of the interface is not as yet clear.

A typical set of data illustrating the effect of core material on pulsed emission is shown in Fig. 5. The data

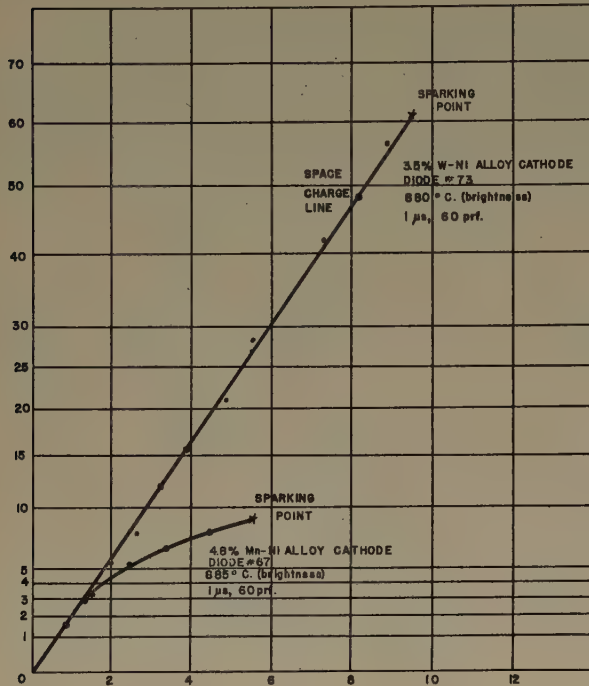


Fig. 5—Effect of the core material on the pulsed emission characteristics of experimental diodes. Ordinate is current in amperes per square centimeter; abscissa is applied anode potential in kilovolts. Draw on  $\frac{3}{4}$ -power paper.

was taken at 880° C., 1 μs, 60 prf. The emission characteristic of the 3.5-per cent W-Ni core tube is typical of that of a good emitter. No falling off of emission from the space-charge limited line could be determined, the emission being limited by sparking. The emission characteristic of the 4.8-per cent Mn-Ni tube is characteristic of a poor emitter. The emission falls away from the space-charge curve at low values, and is ultimately limited by sparking.

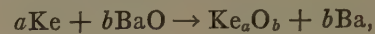
The accuracy of the low-temperature dc measurements is limited by the accuracy with which the cathode temperature could be measured. Uncertainty in determining the temperature of the cold junction of the thermocouple limits temperature measurements to  $\pm 4$  per cent. The emission-current measurements were made to  $\pm 3$  per cent, and the voltage measurements to within  $\pm 2$  per cent. Pulse measurements are within  $\pm 5$  per cent. The temperature, when expressed as "brightness" temperature, could be measured to  $\pm 2$  per cent.

#### DISCUSSION OF RESULTS

The data of Table I show that the core material exerts a marked influence on the thermionic emission of oxide cathodes. The observed influence is in con-

formity with already published theories, as will be shown.

The work of Becker<sup>27</sup> and other<sup>28</sup> has shown that the oxide coating behaves as an impurity semiconductor, small amounts (in the order of 0.2 per cent) of free alkaline-earth metals furnishing the impurity. Furthermore, Prescott and Morrison<sup>29</sup> have shown that the emission of an oxide cathode is dependent on the amount of free barium present in the coating. They found that the thermionic emission increases with the barium content up to a concentration of 30 μg<sup>30</sup> of barium per cm<sup>2</sup> of superficial area. Free barium, however, can be produced by reaction of the core material with the oxide coating, such as



where Ke represents the core metal.

Benjamin<sup>4</sup> advanced the thesis that the emission of nickel-alloy base oxide cathodes was related to the reducing power of the additive alloyed with the nickel. He used the heats of formation of the most likely formed oxides as a measure of the reducing power. In this manner he was able to explain the emission of 2-per cent Al-Ni, 0.07-per cent Mg-Ni, and 0.34-per cent Mn-Ni alloys. The emission of pure nickel, however, was out of place in this scheme, and Benjamin attributed this to small traces of reducing elements in the pure nickel, in spite of the fact that the other alloys were made using the same pure nickel as base.

In an investigation of the thermionic emission of oxide cathodes using eleven different core materials, Liebold found<sup>5,28</sup> that his results could not all be explained by the theory of Benjamin. He proposed a modified theory, into which the experimental data obtained here fits.

Benjamin divided the core materials into two groups: (a) those core materials for which the most probably formed interface oxides have a dissociation pressure, or a vapor pressure, higher than that existing in the tube (about  $10^{-6}$  mm), at the operating temperatures; and (b) those core materials for which the dissociation pressure and vapor pressure of the most probably formed interface oxides are lower than the pressure existing in the tube.

In the first group, the interface compounds that are formed do not persist. As soon as they are formed, they decompose, giving off oxygen, or they are evaporated away. Hence, no interface is formed. For these cores, basing Ba formation on the reduction of BaO by the core, Liebold concludes that the thermionic emission should increase with the reducing power of the core. To

<sup>27</sup> J. Becker, "Phenomena in oxide-coated filaments," *Phys. Rev.*, vol. 34, p. 1323; 1929.

<sup>28</sup> G. Herrmann and S. Wagener, "Die Oxydkathode," Johann Barth, Leipzig, Germany; 1943.

<sup>29</sup> C. Prescott and J. Morrison, "The oxide-coated filament," *Jour. Amer. Chem. Soc.*, vol. 60, p. 3047; 1938.

<sup>30</sup> Per 1 mg BaO, 1 mg SrO of coating.

this extent Liebold's theory is the same as Benjamin's. Indeed, Liebold found that the thermionic emission of Au, Pt, Pd, Cu, and Ni increased with the heats of formation<sup>31</sup> of the oxides most probably formed at the interface. These oxides all have dissociation pressures above  $3 \times 10^{-6}$  mm.

For the second group, an interface compound is formed that persists. This interface, by its interposition, retards the reduction by the core metal of BaO to Ba, and does so to a larger degree as it grows in thickness. Indeed, Liebold found that for W, Mo, Ta, Cr, and Zr, the emission decreased as the heats of formation of the most probably formed oxides increased. The dissociation and vapor pressures of all these oxides are considerably below  $10^{-6}$  mm.

Finally, Liebold explains the high thermionic activity of pure, nickel-base oxide cathodes. According to Liebold, the heat of formation of the nickel oxide is just large enough to supply a sufficient reduction of BaO to Ba, without, at the same time, the dissociation pressure of NiO ( $3 \times 10^{-6}$  mm at  $950^\circ$  C) being so low as to permit an appreciable interface formation. Finally, the dissociation pressure is not so large that the oxygen liberated by the dissociation of NiO is too much for the getter to handle; otherwise, the cathode would soon be poisoned by oxygen.

The results that were obtained for the 3.5-per cent W-Ni alloy may at first seem to be a contradiction because Liebold, in testing the emission of pure tungsten core oxide cathodes, found their emission to be inferior, and noted the presence of an interface formation, which he concluded was probably  $WO_2$ . However, this contradiction is resolved when we remember that a large part of the interface formation takes place during the breakdown of the carbonate to the oxide, as a result of the thermal dissociation of  $2CO_2$  to  $O_2$  and  $2CO$ , and with the subsequent oxidation of the W core by the  $O_2$ . However, since the core is a 96.5-per cent Ni-3.5-per cent W alloy, instead of pure tungsten, not as much tungsten is accessible to the oxygen during the brief (3 to 4 minutes) carbonate-to-oxide breakdown procedure. As a result, a relatively smaller interface is formed. Furthermore, if it can be assumed that the tungsten alloyed in the core gradually diffuses to the surface where it is removed by combination with the oxygen of the BaO to form Ba (noting that the heats of formation indicate that W is more active in reducing BaO to Ba than Ni), it becomes understandable that the 3.5-per cent W-Ni alloy, when used as the base of an oxide cathode, yields a more efficient emitter than pure

nickel. The sparking-current data for the 3.5-per cent W-Ni alloy supports this view.

The results obtained with a 0.38-per cent Mg-Ni alloy, when used as core, show thermionic emissions inferior to that of pure nickel. Rooksby<sup>32</sup> has noted that an interface compound is formed when nickel containing small amounts of magnesium is used as the core for oxide cathodes, and he analyzed this interface to be MgO. It will be assumed that an MgO interface also is formed in the Mg-Ni cathodes tested here. The low values of sparking current obtained for 0.38-per cent Mg-Ni give further indication of the formation of an interface. Decreased emission of the 0.38-per cent Mg-Ni alloy core oxide cathodes, therefore, is probably due to the formation of an MgO interface which persists and retards the action of the Mg of the core in its reduction of the BaO.

The improved emission reported by Benjamin<sup>4</sup> with 0.07-per cent Mg-Ni as core, and the general use by the Germans of 0.07-per cent Mg-Ni for oxide cathodes during World War II,<sup>33</sup> can be explained by reasoning similar to that applied to the 3.5-per cent W-Ni core. As a result of the small amount of magnesium in the core, the interface formation during conversion of the carbonate to oxide is reduced. The interface that is formed is not sufficient to impede the reducing action of the magnesium in the core.

The results with 4.0-per cent Al-Ni show a reduced emission relative to the use of pure nickel as core. Rooksby<sup>32</sup> has analyzed the interface formed on 2-per cent Al-Ni core oxide cathodes, and found it to be  $BaO \cdot Al_2O_3$ . Unfortunately, data on the dissociation and vapor pressures of this compound are not available. The presence of an interface in the cathodes analyzed by Rooksby, however, indicates that the vapor pressure and the dissociation pressure are below that of normal tube operation. It will be assumed that  $BaO \cdot Al_2O_3$  is the interface formed in our 4.0-per cent Al-Ni cathodes. That an interface is formed also is indicated by the low sparking currents obtained for 4.0-per cent Al-Ni cathodes (Table I).

The thermionic emission, therefore, is reduced for the 4.0-per cent Al-Ni cathodes for the reasons already outlined for the 0.38-per cent Mg-Ni alloy. The emission in this case is inferior to that obtained by Benjamin because of the increased aluminum content, the discussion being similar to that given for 0.38-per cent Mg.

Finally, the emission of 4.8-per cent Mn-Ni alloy was found to be considerably inferior to that of pure nickel. Benjamin<sup>4</sup> in his work with 0.34-per cent Mn also found it to be the worst of 0.07-per cent Mg-Ni, 2-per cent Fe-Ni, 2-per cent Al-Ni, and 0.2-per cent Th-Ni. No data on the interface compound of an Mn-Ni alloy oxide cathodes is available. In a manner

<sup>31</sup> It is to be noted that, strictly speaking, the heats of formation cannot be used as a guide to the reducing power of an element, but rather it is the free energy of the reaction that is the determining factor. Heats of formation, when used as a guide of reducing power, will give the correct result only when the entropies involved are the same for all the reactions compared. Furthermore, the values of the thermodynamic constants at the temperatures of the reaction should be taken, and not the values for room temperatures, as is so commonly done. Finally, it should be pointed out that the free energies in a reaction do not determine the rate of the reaction.

<sup>32</sup> H. Rooksby, "Application of X-ray technique to individual laboratory problems," *Jour. Roy. Soc. A.*, vol. 88, p. 308; 1940.

<sup>33</sup> T. Briggs, "European practices in the manufacture of cathodes," *Proc. I.R.E.*, vol. 36, p. 376; March, 1948.

similar to the other alloys, an interface compound probably is formed, reducing the emission for the reasons discussed for the 0.38-per cent Mg-Ni and 4.0-per cent Al-Ni alloys. The pulsed-emission data for the 4.8-per cent Mn-Ni alloy given in Table I are the lowest for all the alloys tested. The emission of the 4.8-per cent Mn-Ni alloy base oxide cathodes, however, is so reduced that it seems likely that another factor is at work. One such factor might be the formation of an interface compound that can oxidize barium.

## ACKNOWLEDGMENT

The author wishes to express his appreciation to the Radio Receptor Company for the grant of a Radio Receptor Fellowship, to the Sylvania Electric Products Company, and to the Bell Telephone Laboratories for specialized services, such as hydrogen firing, to the International Nickel Company for the grant of the nickel alloys used as cores, and to Professor J. B. Russell of the Electrical Engineering Department of Columbia University.

## APPENDIX

TABLE II

QUANTITATIVE CHEMICAL ANALYSIS OF THE NICKEL ALLOYS\*

Type	INCO melt No.	Si	Mg	C	Mn	Fe	Cu	S	Ni+Co	Other	Ni	Co
Grade A	—	0.20% max.	—	0.20% max.	0.35% max.	0.30% max.	0.25% max.	0.008% max.	99.00 min.	—	—	—
Electrolytic Ni	12808	0.03%	0.027%	0.012%	—	—	—	—	—	—	Remainder 0.76%	
0.38% Mg-Ni	12811	0.03%	—	0.012%	—	—	—	—	—	0.38% Mg	Remainder 0.76%	
4.0% Al-Ni	12827	0.03%	0.027%	0.012%	—	—	—	—	—	4.01% Al	Remainder 0.76%	
4.8% Mn-Ni	12888	0.03%	0.027%	0.012%	—	—	—	—	—	4.83% Mn	Remainder 0.76%	
3.5% W-Ni	12890	0.03%	0.027%	0.012%	—	—	—	—	—	3.48% W	Remainder 0.76%	

\* A qualitative spectrochemical analysis is given in Table III.

† This special series of nickel melts, together with the analyses, was kindly supplied by the International Nickel Company, through the courtesy of Mr. E. M. Wise. Melt No. 12808 is the base melt to which Al, Mn, Mg, and W are added to obtain the other nickel alloys. The analysis is for the ingot.

TABLE III

SPECTROCHEMICAL QUALITATIVE ANALYSIS\* OF THE NICKEL ALLOYS AND OF THE EMISSION MIXTURE

	Estimated range	Electrolytic nickel	0.38% Mg-Ni alloy	4.0% Al-Ni alloy	4.8% Mn-Ni alloy	3.5% W-Ni alloy	Raytheon emission mixture C-51-2
Principal component	>10%	Ni	Ni	Ni	Ni	Ni	Ba, Sr
Major component	> 1%	—	—	Al	Mn	W	—
Minor component	0.1-3%	Co	Co, Mg	Co	Co	Co	Ca, Na
Impurities	0.01-0.3%	Fe, Mn, Si, Mg	Fe, Mn, Si, Ca	Fe, Mn, Si, Mg, Pb, Na	Fe, Cr, Si	Fe, Mn, Si, Zn	Mg
Traces	<0.03%	Ca, Cu, Na	Cu, Na, Pb	Ca, Cu, Cr, Zn	Ca, Cu, Na, Pb, Mg	Cu, Na, Pb, Mg, Ca, Cr	Pb
Faint traces	—	—	—	—	—	—	Al, Bi, Cu, Fe, Mn, Ni, Si

\* Furnished through the courtesy of Dr. L. A. Wooten; analysis by Mr. W. Hartmann, Bell Telephone Laboratories. Analysis is for the rolled nickel sheet from which the cathodes were formed.



# A Generalized Method for Analyzing Servomechanisms\*

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**Summary**—Through the use of the algebra of dyadics a unification of dc and ac servo theory is obtained. The effects arising from the asymmetry of the sidebands in an ac (carrier-frequency) servo are automatically taken into account. In the case of a symmetrical sideband carrier-frequency servo or a dc servo, the generalized operators introduced reduce to the ordinary transfer functions of the system components.

## I. INTRODUCTION

THE PROBLEM of obtaining an expression for the loop transfer function of a carrier-frequency servomechanism cannot be handled by the usual methods of servo analysis. That is to say, the concept of transfer function is not applicable unless one is willing to assume that the frequency function of the components involved is symmetrical about the carrier frequency. Often such an assumption is valid, and leads to a good engineering design of a carrier-frequency servo system. On the other hand, this assumption, if made without due consideration, can lead to a poorly designed system.

Further, if the servo contains a frequency-sensitive network such as a parallel tee, the assumption of symmetrical sidebands precludes the possibility of obtaining information concerning the off-frequency operation of the servo system.

Once the loop-transfer function of the servo has been obtained, be it an ac or a dc servo, the usual methods of analysis for determining the transient response, or for testing the stability of the servo, may be employed. The central problem is that of obtaining the loop-transfer function of the servo, and that is the problem which is considered here.

Sobczyk<sup>1</sup> recently presented a method by which error lead-stabilized carrier-frequency servomechanisms may be analyzed. The present paper is, in a sense, a generalization of Sobczyk's work since it presents a method by which any type of carrier-frequency servomechanism may be analyzed. The analysis of dc servomechanisms, which has been exhaustively treated in recent literature, appears as a degenerate case of the technique presented here. The technique employs the theory of linear spaces in the particular form of the algebra of dyadics.<sup>2</sup> Through the use of this algebra, the concept of transfer

function is generalized to that of transfer-operator. The transfer operators so defined behave with respect to carrier-frequency servos in much the same manner that transfer functions behave with respect to dc servos. Further, these transfer operators reduce to transfer functions in case that concept is applicable, as is the case with symmetrical sideband or dc servos.

## II. THE VECTOR REPRESENTATION OF CARRIER-FREQUENCY VOLTAGES

In dc servo theory, it is usual and useful to represent a voltage of the form

$$v = K \cos(mt + \phi) \quad (1)$$

by means of the complex function

$$V = Ke^{j(mt+\phi)}, \quad (2)$$

where

$$j = \sqrt{-1}.$$

In this paper, voltages of the form

$$v = K \cos(mt + \phi) \cos(\omega_c t + \theta) \quad (3)$$

will be encountered where the factor  $\cos(\omega_c t + \theta)$  is called the carrier, and  $\omega_c$  is called the carrier (angular) frequency. The quantity  $m$  is called the modulating (angular) frequency and  $\phi$  and  $\theta$  are respectively the modulation and carrier phase shifts. The entire expression  $v$  will be recognized as a suppressed-carrier modulated voltage.

The voltage  $v$  of equation (3) may be represented uniquely as a vector,  $V$ , having a complex argument. Thus,

$$V = i_\theta K e^{j(mt+\phi)}. \quad (4)$$

Here  $i_\theta$  is a unit vector which makes an angle  $\theta$  with some reference line defined by the base vector  $i_0$ , and represents the carrier  $\cos(\omega_c t + \theta)$ .

In (4), the frequency  $\omega_c$  of the carrier is nowhere noted, being understood. In systems in which more than a single frequency appears as, for example, in systems using demodulators or frequency changers, it is advisable to indicate the frequency,  $\omega_c$ , to which the unit vector refers. In such cases  $\omega_c$  may be used as a superscript and (4) may be written

$$V = i_\theta^{\omega_c} K e^{j(mt+\phi)}. \quad (4a)$$

To unify the notation for dc and for carrier-frequency systems, it becomes necessary to represent the voltage  $v$  given by (1) as a vector. Thus, in the system of repre-

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† Sperry Gyroscope Co., Great Neck, N. Y.

<sup>1</sup> A. Sobczyk, "Stabilization of carrier frequency servomechanisms," *Jour. Frank. Inst.*, vol. 246; July, 1948.

<sup>2</sup> L. Page, "Introduction to Theoretical Physics," D. Van Nostrand Co., Inc., New York, N. Y.; 1935.

sensation adopted here, the voltage  $v = K \cos(mt + \phi)$  is written

$$v = K \cos(mt + \phi) \cos(0 \cdot t + 0) \quad (1a)$$

and is represented by the vector

$$V = i_0^0 K e^{j(mt + \phi)} \quad (2a)$$

### III. REPRESENTATION OF A LINEAR NETWORK

A linear network is completely characterized by its (complex) transfer function  $G(j\omega)$ . This function, it will be recalled, specifies the amplitude ratio and phase shift to which an input sinusoid is subjected in the steady state, when the sinusoid is impressed on the network. Thus if a voltage

$$v_1 = A \cos(mt + \phi) \quad (5)$$

is impressed on a network with transfer function  $G(j\omega)$  the steady state output  $v_0$  is given by

$$v_0 = A |G(j\omega)| \cos[mt + \phi + \text{arc } G(j\omega)]. \quad (6)$$

It is the fact that form of the voltage (5) is left invariant in the steady state by the linear network, which makes it possible to utilize the concept of transfer function.

If a voltage of the form

$$v_1 = K \cos(mt + \theta_1) \cos(\omega_c t + \theta_2) \quad (7)$$

is impressed on a linear network, its form is not left invariant. In fact, the steady state output voltage  $v_0$  is

$$v_0 = K_1 \cos(mt + \phi_1) \cos(\omega_c t + \phi_2) + K_2 \sin(mt + \phi_1) \sin(\omega_c t + \phi_2). \quad (8)$$

However, if a more general voltage, namely,

$$v_1 = K_1 \cos(mt + \theta_1) \cos(\omega_c t + \theta_2) + K_2 \sin(mt + \theta_1) \sin(\omega_c t + \theta_2) \quad (9)$$

is impressed on a linear network, the form of the output is the same as the form of the input, the output voltage being

$$v_0 = C_1 \cos(mt + \psi_1) \cos(\omega_c t + \psi_2) + C_2 \sin(mt + \psi_1) \sin(\omega_c t + \psi_2). \quad (10)$$

The voltages  $v_1$ , and  $v_0$  are representable in the forms

$$V_1 = i_{\theta_2} K_1 e^{j(mt + \theta_1)} + i_{\theta_2 - \pi/2} K_2 e^{j(mt + \theta_1 - \pi/2)} \quad (11)$$

and

$$V_0 = i_{\psi_2} C_1 e^{j(mt + \psi_1)} + i_{\psi_2 - \pi/2} C_2 e^{j(mt + \psi_1 - \pi/2)}. \quad (12)$$

The linear network may be thought of as a transformation,  $n$  which carries  $v_1$  into  $v_0$  and as such may be represented by another transformation  $N$  which carries the vector  $V_1$  into the vector  $V_0$ . This transformation is a tensor of order 2 and the generalization of the transfer function  $G(j\omega)$ . In what follows, dyadic notation will be used, and hence the representation  $N$  of the network transformation,  $n$ , will be called the net-

work transfer dyadic, or transfer operator of the network. Its form will now be derived explicitly.

Let the voltage

$$v_1 = K_1 \cos(mt + \theta_1) \cos(\omega_c t + \theta_2) + K_2 \sin(mt + \theta_1) \sin(\omega_c t + \theta_2) \quad (13)$$

be impressed on a network with transfer function  $G(j\omega)$ . Define

$$G[j(\omega_c + m)] = G^+ e^{j\tau^+}$$

$$G[j(\omega_c - m)] = G^- e^{j\tau^-}$$

$$\phi_1 = \frac{1}{2}(\gamma^+ - \gamma^-)$$

$$\phi_2 = \frac{1}{2}(\gamma^+ + \gamma^-)$$

$$A_1 = \frac{1}{2}(G^- + G^+)$$

$$A_2 = \frac{1}{2}(G^- - G^+).$$

The steady state output voltage of the network may then be written

$$v_0 = (K_1 A_1 + K_2 A_2) \cos(mt + \theta_1 + \phi_1) \cos(\omega_c t + \theta_2 + \phi_2) + (K_1 A_2 + K_2 A_1) \sin(mt + \theta_1 + \phi_1) \sin(\omega_c t + \theta_2 + \phi_2). \quad (14)$$

The network transformation,  $n$ , then transforms the voltage  $v_1$  of (13) into the voltage  $v_0$  of (14). Since the voltages  $v_1$  and  $v_0$  may be represented in vector form by the vectors  $V_1$  and  $V_0$ , respectively, where

$$V_1 = i_{\theta_2} K_1 e^{j(mt + \theta_1)} + i_{\theta_2 - \pi/2} K_2 e^{j(mt + \theta_1 - \pi/2)} \quad (15)$$

and

$$V_0 = i_{\theta_2 + \phi_2} (K_1 A_1 + K_2 A_2) e^{j(mt + \theta_1 + \phi_1)} + i_{\theta_2 + \phi_2 - \pi/2} (K_1 A_2 + K_2 A_1) e^{j(mt + \theta_1 + \phi_1 - \pi/2)}. \quad (16)$$

The network transformation  $n$  may be represented by the dyadic

$$N = i_{\theta_2 + \phi_2} i_{\theta_2} A_1 e^{j\phi_1} + i_{\theta_2 + \phi_2} i_{\theta_2 - \pi/2} A_2 e^{j(\pi/2)} e^{j\phi_1} + i_{\theta_2 + \phi_2 - \pi/2} i_{\theta_2} A_2 e^{-j(\pi/2)} e^{j\phi_1} + i_{\theta_2 + \phi_2 - \pi/2} i_{\theta_2 - \pi/2} A_1 e^{j\phi_1}. \quad (17)$$

The vector representing the output of the network is then related to the vector representing the input by the relation

$$V_0 = N \cdot V_1. \quad (18)$$

The similarity of form between (18) and the expression

$$E_0 = G(j\omega) E_1, \quad (19)$$

which holds between the input and output when a simple sinusoidal voltage  $E_1$  is impressed on the network, is striking. The vectors  $V_0$  and  $V_1$  replace the voltages  $E_0$  and  $E_1$  respectively, and the transfer dyadic  $N$  replaces transfer function  $G(j\omega)$ .

### IV. SYMMETRICAL SIDEBAND NETWORKS

A linear network is said to be a symmetrical sideband network with respect to  $\omega_0$  if<sup>3</sup>

<sup>3</sup>  $G^*$  is the complex conjugate of  $G$ .

$$G[j(\omega_0 + m)] = G^*[j(\omega_0 - m)] \quad (20)$$

for all  $m \geq 0$ .

If the network under consideration is a linear passive network with a finite number of real positive circuit elements consisting of resistors, condensers and inductors, then it is always true that<sup>4</sup>

$$G(jm) \equiv G^*(-jm) \quad (21)$$

so that all such networks are symmetrical sideband networks with respect to  $\omega_0 = 0$ .

Since for the networks under consideration, the transfer functions  $G(j\omega)$  are rational functions of  $j\omega$ , these networks cannot in general be symmetrical sideband networks with respect to a frequency  $\omega_0$  other than 0.

Even though this is the case, it is often true that real networks very nearly approximate the condition for symmetrical sidebands, and for the purpose of synthesizing carrier-frequency servomechanisms, it is often adequate to assume that the network under consideration is a symmetrical sideband network. This assumption usually simplifies the system equations considerably. It is because of this that these networks are of particular interest. Another reason that these networks are of interest is because they always arise in the theory of dc servos.

The main properties of symmetrical sideband networks are readily obtained.

Since

$$G[j(\omega_c + m)] \equiv G^*[j(\omega_c - m)]$$

$$G^+ \equiv G^- \quad \gamma^+ \equiv \gamma^-,$$

hence

$$A_1 \equiv G^+ \quad A_2 \equiv 0$$

$$\phi_1 \equiv \gamma^+ \quad \phi_2 \equiv 0.$$

In this case the network transfer operator is

$$N = i_{\theta_2} i_{\theta_2} A_1 e^{i\phi_1} + i_{\theta_2 - \pi/2} i_{\theta_2 - \pi/2} A_1 e^{i\phi_1} \quad (22)$$

or

$$N = SG^+ e^{i\gamma^+},$$

where  $S$  is the idemfactor or unit dyadic.<sup>2</sup> Thus, in the case of symmetrical sideband networks, the network transfer operator has the simple form given by (22).

If  $\omega_c = 0$  so that the servo under consideration is a dc servo, it is seen that

$$N = S^0 G(jm), \quad (23)$$

where the superscript is included to indicate that  $\omega_c = 0$ , which is the usual transfer function employed in the treatment of dc servos if the idemfactor is disregarded. This shows that the network transfer dyadic as de-

fined here is a logical generalization of the transfer function of a network, in the sense that it reduces to the transfer function in the simpler case of a dc or of any symmetrical sideband servo.

From (18) it follows that if an input

$$v_1 = K_1 \cos(mt + \theta_1) \cos(\omega_c t + \theta_2) \quad (24)$$

is applied to a symmetrical sideband network with respect to  $\omega_c$ ,

$$V_0 = SG^+ e^{i\gamma^+} \cdot i_{\theta_2} K_1 e^{j(mt + \theta_1)} = i_{\theta_2} K_1 G^+ e^{j(mt + \theta_1 + \gamma^+)} \quad (25)$$

$$v_0 = K_1 |G[j(\omega_c + m)]| \cos(mt + \theta_1 + \gamma^+) \cos(\omega_c t + \theta_2),^* \quad (26)$$

which shows that a network which has sidebands symmetrical with respect to the carrier frequency, does not phase-shift the carrier. In fact, the output is found by allowing the network transfer function taken relative to  $\omega_c$ , i.e.,  $G[j(\omega_c + m)]$ , to operate on the modulation alone. The carrier is preserved by the network. Thus, symmetrical sideband networks may be analyzed by the usual techniques employed in dealing with dc systems.

## V. THE TWO-PHASE INDUCTION MOTOR

The two-phase induction motor is the power device used in most carrier-frequency servo systems of the instrument type. Hence, it is necessary to characterize this device before a discussion of carrier-frequency servos can be given.

It is possible beforehand to guess the nature of the transfer entity which must be associated with the two-phase induction motor. The motor accepts as input a suppressed-carrier modulated voltage, and gives as output a shaft rotation. For a complete unification of ac and dc servos, shaft rotations and dc voltages should be treated as vector quantities. The notation by which this may be done was illustrated in (2a). However, while such a notation leads to a complete unification, it is more cumbersome than the notation in which shaft rotations and dc voltages are treated as scalar quantities, as was done in (2). Agreeing then that shaft rotations and dc voltages are to be regarded as scalar quantities, the two-phase induction motor must be represented by an entity which transforms a vector to a scalar. Hence, the motor-transfer operator will be a vector whose scalar product with the vector representing the input, will give the scalar representing the output.

If  $Kv_1$  represents the voltage applied to the control winding of the motor, and if  $-K \cos(\omega_c t + \phi_0 - \pi/2)$  is the voltage applied to the reference winding of the motor, then the differential equation governing the position of the output,  $\theta_0$ , of the motor will be taken to be<sup>1</sup>

$$\tau \ddot{\theta}_0 + \dot{\theta}_0 = 2\omega_c v_1 \cos(\omega_c t + \phi_0) - 2\dot{v}_1 \cos\left(\omega_c t + \phi_0 - \frac{\pi}{2}\right), \quad (27)$$

<sup>4</sup> James, Nichols, and Phillips, "Theory of Servomechanisms," McGraw-Hill Book Co., Inc., New York, N. Y., p. 66; 1947.

where  $\tau$  is a time constant associated with the motor and the load. It is convenient to rewrite (27) as two equations:

$$\begin{aligned}\tau\ddot{\theta}_0 + \dot{\theta}_0 &= \rho(t) \\ \rho(t) &= 2\omega_c v_1 \cos(\omega_c t + \phi_0) \\ &\quad - 2\dot{v}_1 \cos\left(\omega_c t + \phi_0 - \frac{\pi}{2}\right).\end{aligned}\quad (28)$$

If  $v_1$  is taken to be the suppressed-carrier modulated voltage,

$$\begin{aligned}v_1(t) &= K_1 \cos(mt + \theta_1) \cos(\omega_c t + \phi_0 + \lambda) \\ &\quad + K_2 \sin(mt + \theta_1) \sin(\omega_c t + \phi_0 + \lambda),\end{aligned}\quad (29)$$

then except for terms of frequency,  $2\omega_c$ ,  $\rho(t)$  is given by

$$\begin{aligned}\rho(t) &= (2\omega_c K_1 - mK_2) \cos \lambda \cos(mt + \theta_1) \\ &\quad + (2\omega_c K_2 - mK_1) \sin \lambda \sin(mt + \theta_1),\end{aligned}\quad (30)$$

and it is thus seen that if a suppressed-carrier modulated voltage,  $v_1(t)$  is applied, the motor acts like a dc motor to which a voltage  $\rho(t)$  is applied. It is further seen that  $\rho(t)$  is a demodulated version of the voltage  $v_1(t)$ .

Now if the voltage  $v_1(t)$  is represented in vector form,

$$V_1 = i_{\phi_0+\lambda} K_1 e^{j(mt+\theta_1)} + i_{\phi_0+\lambda-\pi/2} K_2 e^{j(mt+\theta_1-\pi/2)},\quad (31)$$

and the response  $\rho(t)$  is written in the complex form,

$$\begin{aligned}P &= (2\omega_c K_1 - mK_2) \cos \lambda e^{j(mt+\theta_1)} \\ &\quad + (2\omega_c K_2 - mK_1) \sin \lambda e^{j(mt+\theta_1-\pi/2)},\end{aligned}\quad (32)$$

it is seen that the demodulating portion of the two-phase induction motor can be described by the transfer operator  $D$  where

$$D = i_{\phi_0} 2\omega_c + i_{\phi_0-\pi/2} m e^{-j(\pi/2)}.\quad (33)$$

The complex function  $P$  is then given by

$$P = D \cdot V_1.\quad (34)$$

Letting  $\Theta_0$  be the complex function representing the output,  $\theta_0$ , of the motor, it follows from the first of (28) that

$$\Theta_0 = \frac{P}{im(1+j\tau m)}\quad (35)$$

or, using (34),

$$\Theta_0 = \frac{D}{im(1+j\tau m)} \cdot V_1 = M \cdot V_1,\quad (36)$$

and it is seen that the two-phase induction motor is described by the transfer vector  $M$  where

$$M = \frac{D}{jm(1+j\tau m)} = \frac{i_{\phi_0} 2\omega_c + i_{\phi_0-\pi/2} m e^{-j(\pi/2)}}{jm(1+j\tau m)}.\quad (37)$$

#### VI. THE INDUCTION TACHOMETER

The induction tachometer is a device which is often used to stabilize servomechanisms. In most applications,

the tachometer is driven by the servo output shaft, and its output voltage is fed back to the input through appropriate networks to accomplish the stabilization. Besides the input shaft and the output winding, the tachometer also has another winding, the reference winding, which is usually supplied with an appropriately phased constant-amplitude voltage of frequency equal to that of the carrier.

If the voltage applied to the reference winding is proportional to  $v_c$  and if  $\theta$  is the position of the input shaft, then the output voltage of the tachometer is given by

$$v_0 = -K \frac{d}{dt} (v_c \theta).\quad (38)$$

Of particular interest is the case where the reference voltage is sinusoidal. Suppose that the reference voltage is proportional to  $v_1 \cos(\omega_c t + \alpha)$ . Then,

$$v_0 = K_1 [\omega_c \theta \sin(\omega_c t + \alpha) - \dot{\theta} \cos(\omega_c t + \alpha)].\quad (39)$$

If now the motion of the input shaft is also sinusoidal, so that  $\theta$  is proportional to  $\cos(mt + \phi)$ , then

$$\begin{aligned}v_0 &= K_1 [-\omega_c m \sin(mt + \phi) \sin(\omega_c t + \alpha) \\ &\quad + m^2 \cos(mt + \phi) \cos(\omega_c t + \alpha)].\end{aligned}\quad (40)$$

It has therefore been shown that if the input rotation of the tachometer is representable by

$$\Theta = K e^{j(mt+\phi)},\quad (41)$$

and if the voltage applied to the reference winding is also sinusoidal, being proportional to  $v_1 \cos(\omega_c t + \alpha)$ , then the output voltage,  $v_0$ , of the tachometer may be represented by the vector

$$V_0 = K_1 [-i_{\alpha-\pi/2} \omega_c m e^{-j(\pi/2)} + i_{\alpha} m^2] e^{j(mt+\phi)}.\quad (42)$$

As might have readily been anticipated, the transfer operator of the tachometer is a vector which, when multiplying the scalar representing the input rotation, gives the vector representing the output. From (41) and (42), the transfer operator of the tachometer is seen to be the vector,

$$T = -K_r \left[ i_{\alpha-\pi/2} m e^{-j(\pi/2)} - i_{\alpha} \frac{1}{\omega_c} m^2 \right].\quad (43)$$

The output voltage of the tachometer is represented by

$$V_0 = T\Theta.\quad (44)$$

#### VII. LOOP TRANSFER FUNCTIONS OF SERVO CONFIGURATIONS

The two carrier-frequency servo configurations most commonly used in practice are shown in Figs. 1 and 2. These are, respectively, an error lead-stabilized servo, and a servo stabilized by tachometric feedback.

Referring to Fig. 1 on page 201, the following expression may be written

$$\Theta_0 = (N \cdot V_0) K_A \cdot M. \quad (45)$$

Writing  $V_e$  and  $\Theta_0$  in the forms

$$V_e = i_0 e^{jmt} \quad (46)$$

$$\Theta_0 = \theta_0 e^{jmt}, \quad (47)$$

it follows that

$$\frac{\theta_0}{\epsilon} = K_A (N \cdot i_0) \cdot M, \quad (48)$$

which is the required loop transfer function.

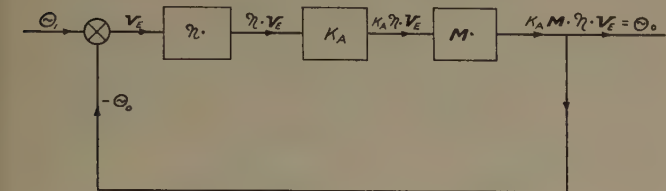


Fig. 1—Error lead stabilized servo.

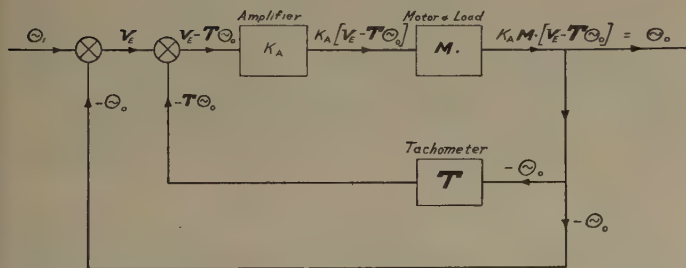


Fig. 2—Servo with tachometric feedback.

Referring to Table I, where the transfer operators of

various servo components are tabulated, (48) may be expanded.

Carrying through this expansion,

$$\frac{\theta_0}{K_v \epsilon} = \frac{[(2\omega_c A_1 - m A_2) \cos \phi - j(2\omega_c A_2 - m A_1) \sin \phi] e^{j\phi_1}}{2\omega_c |G(j\omega_c)| j m (1 + j\tau m)}, \quad (49)$$

where

$$\phi = \phi_2 - \phi_0. \quad (50)$$

and

$$K_v = \lim_{jm \rightarrow 0} jm \left( \frac{\theta_0}{\epsilon} + 1 \right) = 2K_A K_M \omega_c |G(j\omega_c)|. \quad (51)$$

Defining the phase margin  $\phi_M$  by the equation

$$\phi_M = \angle \left( \frac{\theta_0}{K_v \epsilon} \right) - \pi, \quad (52)$$

the amplitude  $|\theta_0/K_v \epsilon|$  of the transfer function and the phase margin become:

$$\left| \frac{\theta_0}{K_v \epsilon} \right| = \frac{[(2\omega_c A_1 - m A_2)^2 \cos^2 \phi + (2\omega_c A_2 - m A_1)^2 \sin^2 \phi]^{1/2}}{2\omega_c |G(j\omega_c)| m (1 + \tau^2 m^2)^{1/2}} \quad (53)$$

$$\phi_M = \frac{\pi}{2} + \phi_1 - \tan^{-1} \frac{(2\omega_c A_2 - m A_1) \sin \phi}{(2\omega_c A_1 - m A_2) \cos \phi} - \tan^{-1} \tau m. \quad (54)$$

These results are in complete agreement with those of Sobczyk.<sup>1</sup>

One further comment should be made. The angle,  $\phi$ , given by  $\phi_2 - \phi_0$  can be calculated when  $\phi_0$  has been specified ( $\phi_2$  is known). The specification of  $\phi_0$  corresponds to selecting a phase for the reference winding of the motor. As stated in Table I,  $\phi_0$  should be taken to be the phase of the carrier portion of the motor input when the modulating frequency is zero.

TABLE I

Component	Input	Representation of Input	Representation of Output	Transfer Operator	Notes and Definitions
Linear Network with Transfer Function $G(j\omega)$	$v_1 = K_1 \cos(mt + \theta_1)$ $\times \cos(\omega_c t + \theta_2)$ $+ K_2 \sin(mt + \theta_1)$ $\times \sin(\omega_c t + \theta_2)$	$V_1 = i_{\theta_2} K_1 e^{j(mt + \theta_1)}$ $+ i_{\theta_2 - \pi/2} K_2 e^{j(mt + \theta_1 - \pi/2)}$	$V_0 = N \cdot V_1$	$N = i_{\theta_2 + \phi_2} i_{\theta_2} A_1 e^{j\phi_1}$ $+ i_{\theta_2 + \phi_2} i_{\theta_2 - \pi/2} A_2 e^{j(\pi/2)} e^{j\phi_1}$ $+ i_{\theta_2 + \phi_2 - \pi/2} i_{\theta_2} A_2 e^{-j(\pi/2)} e^{j\phi_1}$ $+ i_{\theta_2 + \phi_2 - \pi/2} i_{\theta_2 - \pi/2} A_1 e^{j\phi_1}$	$A_1 = \frac{1}{2}[G^- + G^+]$ $A_2 = \frac{1}{2}[G^- - G^+]$ $\phi_1 = \frac{1}{2}[\gamma^+ - \gamma^-]$ $\phi_2 = \frac{1}{2}[\gamma^+ + \gamma^-]$ $G^+ e^{j\gamma^+} = G[j(\omega_c + m)]$ $G^- e^{j\gamma^-} = G[j(\omega_c - m)]$
Two Phase Induction Motor with Voltage $-\cos[\omega_c t + \phi_0 - (\pi/2)]$ On the Reference Winding	$v_1 = K_1 \cos(mt + \theta_1)$ $\times \cos(\omega_c t + \phi_0 + \lambda)$ $+ K_2 \sin(mt + \theta_1)$ $\times \sin(\omega_c t + \phi_0 + \lambda)$	$V_1 = i_{\phi_0 + \lambda} K_1 e^{j(mt + \theta_1)}$ $+ i_{\phi_0 + \lambda - \pi/2} K_2 e^{j(mt + \theta_1 - \pi/2)}$	$\Theta_0 = M \cdot V_1$	$M = K_M \frac{i_{\phi_0} 2\omega_c + i_{\phi_0 - \pi/2} m e^{-j(\pi/2)}}{jm(1 + j\tau m)}$	$\lambda = \lambda(m)$ $\lambda(0) = 0$ $\phi_0$ is the phase of the carrier for $m=0$ . The fixed winding of the motor should be excited with a voltage of frequency $\omega_c$ and a phase $\phi_0 - (\pi/2)$ . These conditions have been assumed here.
Induction Tachometer $\cos(\omega_c + \alpha)$ On Reference Winding	$\theta = K \cos(mt + \phi)$	$\Theta = K e^{j(mt + \phi)}$	$V_0 = T \Theta$	$T = -K_T [i_{\alpha - \pi/2} m e^{-j(\pi/2)} - i_{\alpha}(1/\omega_c) m^2]$	If it is desired that the main output term have a sine carrier, take $\alpha=0$ . For a cosine carrier, take $\alpha=\pi/2$ .

The phase of the carrier portion of the motor input voltage is the phase-shift to which the carrier is subjected by the network, namely,  $\phi_2(m)$ . Hence,

$$\phi_0 = \phi_2(0). \quad (55)$$

But also from Table I, it is seen that

$$\begin{aligned} \phi_2(m) &= \frac{1}{2}[\gamma^+(m) + \gamma^-(m)] \\ &= \frac{1}{2}\{\angle G[j(\omega_c + m)] + \angle G[j(\omega_c - m)]\}. \end{aligned} \quad (56)$$

Hence,

$$\phi_0 = \phi_2(0) = \angle G(j\omega_c). \quad (57)$$

Therefore, when the stabilizing network has been specified, the phasing of the motor is also specified. That is,  $\phi_0$  is known.

Referring now to Fig. 2 where a servo with tachometric feedback or an output lead-stabilized servo is shown, the following expression may be written:

$$\Theta_0 = K_A[V_0 - T\Theta_0] \cdot M. \quad (58)$$

Writing

$$V_0 = i_0 e^{j\omega_c t} \quad (59)$$

$$\Theta_0 = \theta_0 e^{j\omega_c t}, \quad (60)$$

it follows that

$$\frac{\theta_0}{\epsilon} = K_A \frac{i_0 \cdot M}{1 + K_A T \cdot M}. \quad (61)$$

By reference to Table I, this may be expanded. The expansion leads to

$$\frac{\theta_0}{\epsilon} = \frac{2\omega_c K_A K_M}{j\omega_c \left[ \left( 1 + 2\omega_c K_A K_r K_M + \frac{1}{\omega_c^2} K_A K_r K_M m^2 \right) + jTm \right]}. \quad (62)$$

These two examples serve to illustrate the ease with which the transfer functions of carrier-frequency servo-mechanisms may be derived by use of the transfer operators of Table I. Note that the expressions derived by this scheme are equally valid whether or not the carrier frequency drifts, and therefore the formulas derived for the loop transfer functions may be used to study the off-frequency behavior of the servo.

## VIII. CONCLUSIONS

The generalization of the concept of transfer function to that of transfer operator permits a complete unification of the techniques of analysis of carrier-frequency servos and dc servos. The transfer operators are combined in the same manner as are transfer functions except that addition and subtraction are replaced respectively by vector addition and subtraction. Multiplication is replaced by the inner product.

The transfer operator of a given component fully describes its behavior in a servo loop, both with regard to its normal behavior, and with regard to its behavior when the carrier frequency shifts. Since, however, the theory is a linear theory, large shifts of the carrier frequency, which result in saturation of the components, cannot be handled.

Finally it should be remarked that the concepts presented here are not restricted to servo theory but are applicable to the analysis of any suppressed-carrier amplitude-modulated transmission system.

# Improvement in Gain Stability of the Superheterodyne Mixer Through the Application of Negative Feedback\*

GAIL E. BOGGS†

**Summary**—The superheterodyne mixer may be stabilized by the employment of the difference-frequency voltage as negative feedback. This results in increased gain stability and, for the case of the mixer couple, in increased gain-bandwidth product. Two mixer cir-

cuits using feedback are described. Generalized design curves are shown and a design procedure is outlined. A description of the experimental mixers and a discussion of the experimental results conclude the paper.

## I. INTRODUCTION

IN THE USE of field intensity and other frequency-selective measuring equipment, it is highly desirable to have the instrument retain gain calibration over reasonably long periods of time.

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One method of mixer stabilization wherein the feedback is applied at signal frequency has been presented by Tucker.<sup>1</sup> Another method is here presented in which the difference frequency is used to stabilize the mixer as an amplifier.

Two types of mixers will be discussed, together with the derivation of their gain equations in order to show the improvement in stability. In addition, a design procedure is given to aid the design engineer.

<sup>1</sup> D. G. Tucker, "Frequency changers and amplifiers with constant gain," *Proc. I.R.E.*, vol. 37, pp. 1324-1327; November, 1949.

III. THEORY OF A FEEDBACK MIXER

In general, it is desirable to use a large voltage of oscillator frequency in order to minimize changes in conversion gain with variations in applied voltage at signal frequency. As a result, the mixer transconductance is driven from maximum on one-half cycle to zero on the other. Obviously the instantaneous transconductance is a function of oscillator voltage. This is shown in Fig. 1.<sup>2</sup>

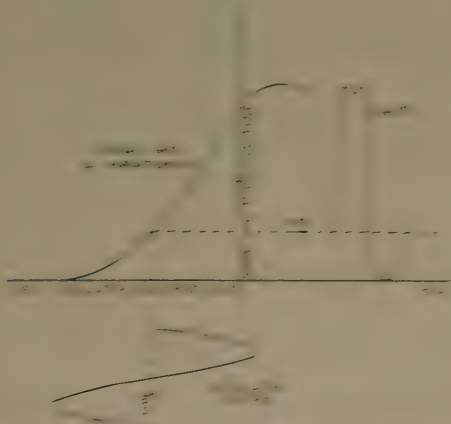


Fig. 1—Transconductance as a function of oscillator voltage.

The instantaneous transconductance can be expressed by the Fourier series

$$g_m = g_0 + a_1 \sin \omega_1 t + a_2 \sin 2\omega_1 t + \dots + b_1 \cos \omega_1 t + b_2 \cos 2\omega_1 t + \dots, \quad (1)$$

where  $\omega_1$  is the angular frequency of the oscillator voltage.

For the type of switching or modulating function generally encountered, the transconductance as a function of time,  $g_m(t)$ , may, as an approximation, be represented by a square wave. Now by well-known methods of Fourier analysis,

$$g_m = \frac{\bar{g}_m}{2} + \frac{2\bar{g}_m}{\pi} \left[ \sin \omega_1 t + \frac{1}{3} \sin 3\omega_1 t + \frac{1}{5} \sin 5\omega_1 t + \dots \right], \quad (2)$$

where  $\bar{g}_m$  is the maximum value of transconductance.

While (1) may often be used in mixer analysis, it has been shown experimentally that sufficient accuracy cannot be obtained when using tubes such as the 6SA7 and 6SB6-Y. Therefore, the switching function for the 6SB6-Y was determined experimentally and is shown in Fig. 2. In this case, the transconductance may be represented by the series

$$g_m = g_0 + a_1 \sin \omega_1 t + a_3 \sin 3\omega_1 t + a_5 \sin 5\omega_1 t + \dots + b_1 \cos \omega_1 t + b_3 \cos 3\omega_1 t + b_5 \cos 5\omega_1 t + \dots, \quad (3)$$

where the constants are obtained by graphical integration. The constants  $a_1$  and  $b_1$  are neglected since, with graphical integration, they contribute very little to the result. Equation (3) may now be applied to the analysis of a simple feedback mixer.

<sup>2</sup>E. W. Herold, "The operation of frequency converters and mixers for superheterodyne reception," *Proc. I.R.E.*, vol. 30, pp. 84-103; February, 1942.

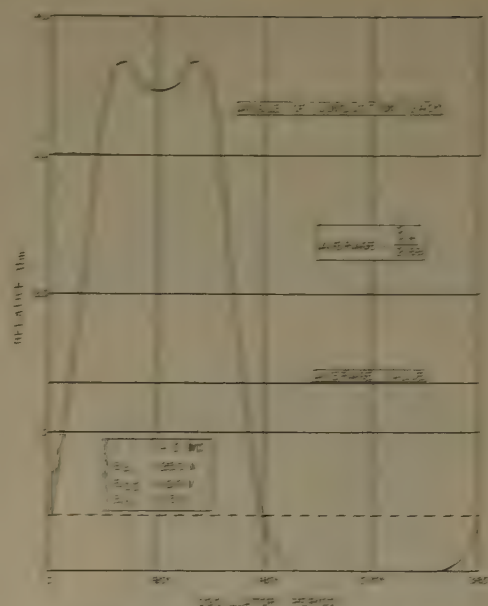


Fig. 2—Switching function 6SB6-Y

Consider the circuit shown in Fig. 3. Let the signal input voltage at angular frequency  $\omega_2$  be

$$e_s = E_s \sin \omega_2 t. \quad (4)$$

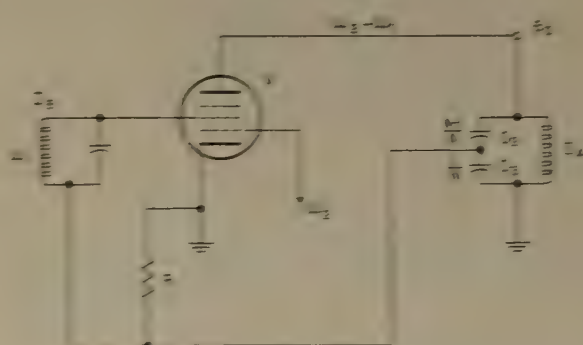


Fig. 3—Schematic diagram of feedback mixer.

Since the output circuit  $Z_L$  is tuned to the difference frequency ( $\omega_1 - \omega_2$ ), only this component need be considered in the output voltage,  $e_o$ , thus,

$$e_o = E_o \cos (\omega_1 - \omega_2)t. \quad (5)$$

The input circuit  $Z_S$  is tuned to the frequency of the incoming signal ( $\omega_2$ ), and hence, its impedance at the difference frequency may be neglected. The feedback voltage is, therefore,  $(1/N)e_o$ , where  $N$  is the stepdown ratio of the tuned output circuit. The grid-to-cathode voltage may now be given as

$$e_g = E_s \sin \omega_2 t + \frac{1}{N} E_o \cos (\omega_1 - \omega_2)t. \quad (6)$$

The output voltage of the mixer is  $g_m e_g Z_L$ .

Substituting the expressions given in (3) and (6) in the foregoing, expanding, and neglecting all terms which do not contain the difference frequency, yields

$$e_0 = \left[ -b_1 \frac{1}{N} E_0 \cos(\omega_2 - \omega_1)t + \frac{a_1 E_s}{2} \cos(\omega_2 - \omega_1)t \right] Z_A.$$

Collecting terms and with the aid of (5),

$$E_0 = \frac{a_1 E_s Z_A}{2 \left( 1 - \frac{b_0 Z_A}{N} \right)} \quad (7)$$

Now by definition, the gain with feedback is,

$$A_f = \frac{E_0}{E_s}.$$

Therefore,

$$A_f = \frac{a_1 Z_A}{2 \left( 1 - \frac{b_0 Z_A}{N} \right)} \quad (8)$$

For simplification let

$$b_0 = k_0 \frac{\hat{g}_m}{\pi} \quad \text{and} \quad a_1 = k_1 \frac{\hat{g}_m}{\pi},$$

where  $k_0$  and  $k_1$  are constants determined by the switching function of the mixer tube selected.

Substituting

$$A_f = \frac{k_1 \hat{g}_m Z_A}{2 \left( \pi - \frac{k_0 \hat{g}_m Z_A}{N} \right)} \quad (9)$$

This expression for the gain of the mixer with feedback is quite similar to the gain expression for a single-stage feedback amplifier.

In (9) it can be seen that when  $(k_0 \hat{g}_m Z_A / N) \gg -\pi$ , the gain to a good approximation is no longer a function of the transconductance. Thus it is shown that the use of the difference-frequency voltage for feedback results in an improvement in the mixer gain stability with changing transconductance.

It should be noted that the constant  $k_1$  is directly proportional to the conversion transconductance, while  $k_0$  is a relative measure of the average value of amplifier transconductance.  $k_0$  and  $k_1$  are subject to variation due to changes in the shape of the switching function which may result from a change in oscillator voltage as well as other causes. While this may be considered as a limiting factor for stability improvement, experimental results indicate that these constants tend to change together. With a high degree of feedback, examination of (9) indicates little change in  $A_f$  with changes in the value of the constants, provided that the changes of  $k_0$  and  $k_1$  are in the same direction and of like percentage. Unfortunately, the stability of the switching function varies with tube types, and this factor must be considered when employing feedback mixers.

### III. A SIMPLE FEEDBACK MIXER

Referring again to Fig. 3, the conversion transconductance  $g_o$  is, by definition  $a_1/2$ . Therefore, the complex gain of the stage as a mixer without feedback is

$(k_1 g_m / 2\pi) Z_A$ . This will be denoted by  $A$ . Substituting in (9) yields

$$A_f = \frac{k_1 A}{\left( k_1 - \frac{2k_0 A}{N} \right)} \quad (10)$$

where  $A = A/1 + jx$ ;  $A$  is the gain at  $f_0$  and  $x = Qu$ ;  $u = (f/f_0) - (f_0/f)$ .

Substituting in (10) and simplifying gives,

$$A_f = \frac{A}{\left( 1 - \frac{2k_0 A}{N k_1} \right) + jx} \quad (11)$$

By definition,

$$B = -\frac{2k_0 A}{N k_1},$$

where  $B$  is the feedback factor; therefore,

$$A_f = \frac{A}{(1 + B) + jx} \quad (12)$$

For design purposes, it is convenient to have an expression for normalized gain in order to determine the selectivity characteristic for varying degrees of feedback. Let the normalized gain be denoted by  $a$ .

Now,

$$a = A_f \frac{1 + B}{A}.$$

Expanding and squaring reals and imaginaries to obtain the magnitude yields

$$a = \left[ \frac{1}{1 + \left( \frac{x}{1 + B} \right)^2} \right]^{1/2} \quad (13)$$

Equation (13) may be plotted in order to allow the design engineer to readily obtain the selectivity characteristic. Note, however, that at the half-power points ( $a = 1/\sqrt{2}$ ),  $x/(1 + B)$  is equal to one.

#### Design Procedure:

Given  $\Delta f$ ,  $f_0$ ,  $A_{f0}$ , and  $g_o$ , where  $A_{f0}$  is the center frequency gain with feedback,  $f_0 = f_2 - f_1$ , and  $\Delta f$  is the bandwidth between half-power points,

(a) Determine values of  $k_0$  and  $k_1$  for the tube under consideration. These constants may be determined experimentally as described.

(b) Choose value of  $1 + B$  and calculate  $Q$  from  $Q(\Delta f/f_0) = 1 + B$  at half-power points. If  $Q$  is impractically large, choose a smaller value of  $1 + B$  and redesign.

(c) Calculate  $C_1 = g_o Q / \omega_0 A_{f0} (1 + B)$ , where  $1/C_1 = (1/C_2) + (1/C_3)$ .

(d) Calculate  $A = A_{f0} (1 + B)$ .

(e) Calculate  $N = 2k_0 A / k_1 B$ .

(f) Calculate  $C_2 = N C_1 / N - 1$

$$C_3 = N C_1.$$

## IV. THE MIXER COUPLE

In applying voltage feedback to either an amplifier or mixer, the bandwidth is usually increased. Since a large amount of feedback is generally required to substantially improve the gain stability, it is apparent that a very high  $Q$  is necessary for a relatively narrow bandwidth.

If feedback is applied over two stages, a relatively narrow bandwidth with improved flatness will result, using a practically obtainable coil  $Q$ . The material following is an adaptation from a paper by G. F. Montgomery,<sup>3</sup> and many of the equations are obtained directly from this work.

The circuit of the mixer couple is shown in Fig. 4. Since a pentagrid mixer is again employed, the switching function given in (3) will be used as a basis for the analysis.

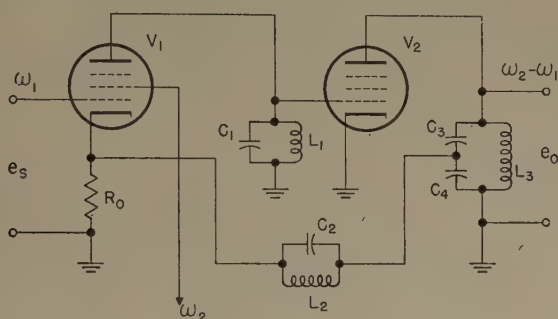


Fig. 4—Schematic diagram of mixer couple.

Let the input voltage at angular frequency  $\omega_1$  be

$$e_s = E_s \cos \omega_1 t.$$

Since the output voltage contains only the difference frequency,

$$e_0 = E_0 \sin (\omega_2 - \omega_1) t.$$

Neglecting local feedback at the cathode, the signal grid voltage is

$$e_g = e_s \frac{e_0 R_0}{(R_0 + Z_0) N};$$

hence,

$$e_0 = \frac{g_{m1} g_{m2} Z_1 Z_3 e_s}{1 + \frac{R_0}{(R_0 + Z_2) N} g_{m1} g_{m2} Z_1 Z_3}.$$

Substituting for  $g_{m1}$  and expanding trigonometric functions,

$$A_c = \frac{E_0}{E_s} = \frac{k_1 \hat{g}_{m1} g_{m2} Z_1 Z_3}{2 \left( \pi + \frac{R_0}{N(R_0 + Z_2)} k_0 \hat{g}_{m1} g_{m2} Z_1 Z_3 \right)}. \quad (14)$$

$A_c$  is the complex voltage gain of the mixer couple. Upon inspection of (14), it is seen that with a high degree of feedback, the gain is largely independent of the tube transconductance.

<sup>3</sup> G. F. Montgomery, "Intermediate frequency gain stabilization with inverse feedback," PROC. I.R.E., vol. 38, pp. 662-667; June, 1950.

Since the balance of this derivation is quite lengthy and follows a pattern similar to that already presented,<sup>3</sup> it will be omitted.

## Design Procedure:

Given  $\Delta f$ ,  $f_0$ ,  $A_{c0}$ ,  $g_{c1}$ , and  $g_{m2}$ , where  $f_0 = f_2 - f_1$  and  $A_{c0}$  = voltage gain of mixer couple at  $f_0$ ,

(a) Determine values of  $k_0$  and  $k_1$  as before.

(b) Choose value of  $1+B$ . In Fig. 5 find  $Q_1(\Delta f/f_0)$ , for  $a = 1/\sqrt{2}$ .

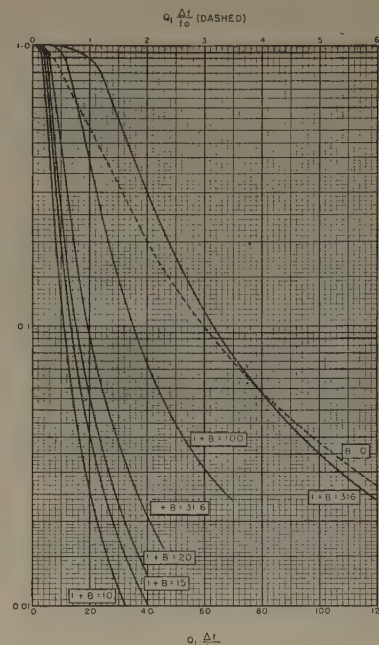


Fig 5—Normalized gain of mixer couple.

(c) Calculate  $Q_1$ . If  $Q_1$  is impractically large, choose a smaller value of  $1+B$ .

(d) Calculate

$$C_1 = \frac{Q_1}{\omega_0} \sqrt{\frac{g_c g_{m2}}{A_{c0}(1+B)}}.$$

(e) Calculate  $R_1 = Q_1/\omega_0 C_1$ .

(f) In Fig. 6 find  $P$  and  $A/N$  for chosen  $1+B$ .

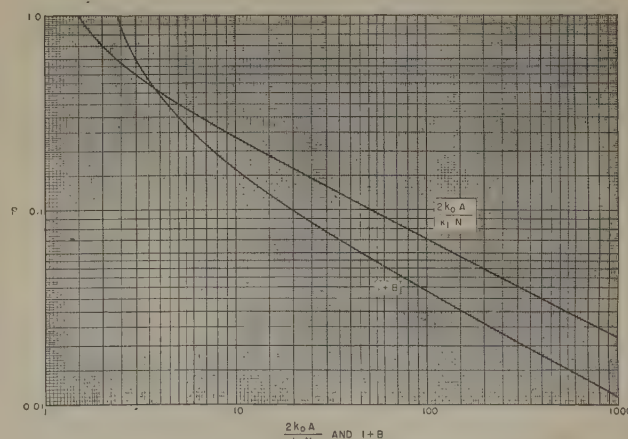


Fig. 6—Design factor chart.

(g) Calculate  $A = (1+B)A_{c0}$  and  $N$ .

(h) Choose  $R_0$  from tube data.

(i) Calculate

$$R_2 = \left( \frac{2k_0A}{k_1BN} - 1 \right) R_0.$$

(j) Verify  $N^2R_2 \gg R_1$ . If this is not true, choose a smaller value of  $1+B$  and redesign.

(k) Calculate  $Q_2 = (AP/BN)Q_1$ .

(l) Calculate  $C_2 = Q_2/\omega_0R_2$ .

(m) Calculate  $C_3 = NC_1/N - 1$

$$C_4 = NC_1.$$

## V. EXPERIMENTAL RESULTS

In the case of either mixer, the electrical arrangement represented in the circuit diagram must be duplicated as closely as possible if results are to match the predictions of the design.

For the simple feedback mixer, the experimental verification is not difficult when the switching function is known. A 6SB7-Y tube was selected because of its high conversion transconductance. The design parameters were:

Given  $\Delta f = 33$  kc,  $f_0 = 450$  kc,  $Af_0 = 3.7$

$$g_c = 740 \mu \text{ mhos}$$

$k_0 = 1.17$ ,  $k_1 = 1.75$ , as determined by graphical integration of the switching function.

Calculated  $1+B=20$ ,  $Q=270$ ,  $C_1=955 \mu\text{mf}$ ,  $R_1=100k$ ,  $1/N=0.194$ ,  $C_2=1,185 \mu\text{mf}$ ,  $A=74$  and  $C_3=4,930 \mu\text{mf}$ .

The experimental results agreed well with prediction, although the bandwidth was slightly narrow, measuring 31 kc.

It was noted that the bandwidth varies with oscillator injection voltage as would be expected since this varies  $A$ . The oscillator excitation was observed to be quite noncritical insofar as gain with feedback was concerned.

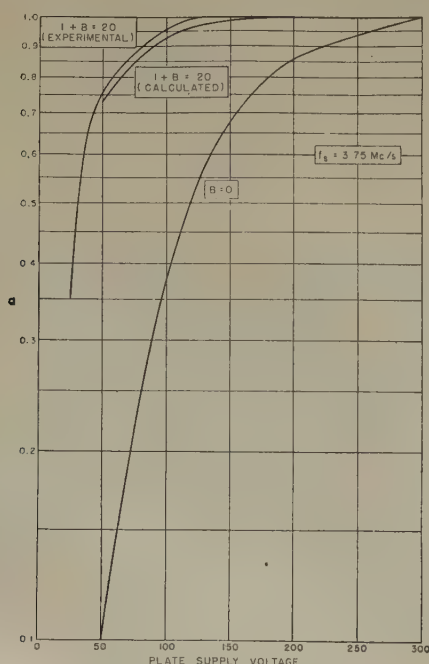


Fig. 7—6SB7-Y gain stability

In Fig. 7 is shown the result of varying the plate-supply voltage. The calculated curve is plotted with reference to the zero feedback curve, on the assumption that the only variable is the tube transconductance. To the extent that this assumption may hold true, the results are thought to be in good agreement with prediction.

The following table will give the reader a good idea of what may be expected with a value of  $1+B=20$ . Examination of this table indicates a considerable improvement in gain stability. It is apparent that a large change in conversion transconductance results in a relatively small change in voltage gain.

TABLE I

$g_c$	$\Delta g_c$	Calculated		Experimental	
		$A_{c0}$	$\Delta A_{c0}$	$A_{c0}$	$\Delta A_{c0}$
770 $\mu\text{mhos}$	— 0 db	3.67	0 db	3.70	0 db
545	— 3	3.60	—0.16	3.70	0
385	— 6	3.51	—0.40	3.65	—0.12
244	—10	3.35	—0.80	3.48	—0.56
77	—20	2.68	—2.74	2.81	—2.36

Before further discussion of the mixer couple experimental results, a few general comments will be made. Due to the increased gain-bandwidth product obtained with the couple, the gain per stage will be larger than for a zero-feedback amplifier. Hence adequate precautions to reduce regeneration, such as shielding and power-lead decoupling, are recommended. The screen grid of the mixer stage should be bypassed directly to the cathode since the formulas for  $R_0$  and  $C_1$  will not be correct if the screen is bypassed to ground.

With the usual values of  $R_0$ , the impedance of the feedback coil may be very small. With a low impedance it may very likely be quite difficult to obtain the required

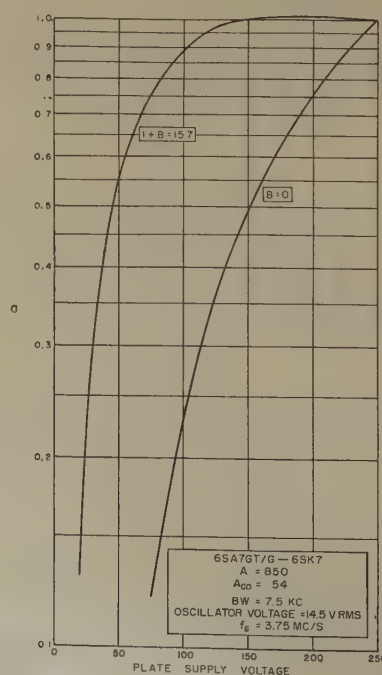


Fig. 8—Mixer-couple gain stability.

$Q_2$ . In that event it is permissible to increase  $R_0$ , provided that the correct bias is maintained. In the derivation presented, it was assumed that the internal cathode impedance of the mixer would be much larger than  $R_0$ . Hence, if  $R_0$  is increased, it is quite possible that the cathode impedance may be less than  $R_0$ ; therefore, the feedback and bandwidth will be reduced. This point should be borne in mind when experimental work is being carried on with the mixer couple.

The experimental mixer couples using 6SA7 or 6SB7-Y mixer tubes followed by a 6SK7 amplifier were found to agree with the calculated results within one db. A normalized curve showing gain variations with plate supply voltage for the 6SA7GT/G mixer is given in Fig. 8. Similar curves for the 6SB7-Y are shown in Fig. 9.

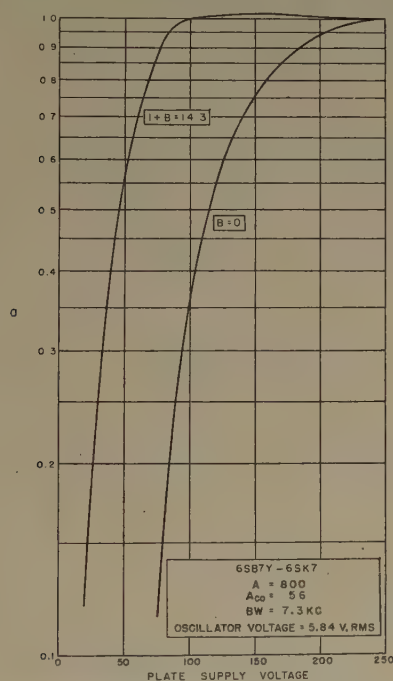


Fig. 9—Mixer-couple gain stability.

Again the oscillator excitation voltage affects  $A$ , but is noncritical for  $A_{c0}$ . In Fig. 9 it is observed that  $A_{c0}$  increases slightly at a reduced plate supply voltage. This effect came about due to slightly deficient oscillator excitation in the experimental setup used.

## VI. CONCLUSION

It has been shown that the difference-frequency voltage may effectively be used as feedback to stabilize the mixer gain. While the oscillator voltage must be carefully adjusted to obtain the correct bandwidth, it is apparent that the gain with feedback,  $A_{c0}$ , is relatively independent of this adjustment.

For the simple mixer, high gain is required in order to apply sufficient feedback to effect an improvement in gain stability. For this reason a tube with a high-conversion transconductance should be selected. Also the tuned plate circuit should have high impedance and high  $Q$ .

Comparing the mixer couple to a cascade, synchronous, single-tuned mixer-amplifier arrangement, the

couple provides improved gain stability, greater flatness, and steeper skirts. Careful attention to the design and construction of the mixer couple is necessary if the results are to closely approximate the calculated values.

The plate circuits are peaked in normal fashion with the feedback line broken. When feedback is applied, the feedback coil is adjusted for a symmetrical response about the center frequency. A peaked response of insufficient bandwidth indicates either that  $Q_2$  is too high or that the cathode impedance of the first tube is too small. If  $R_0$  is fairly large, the latter condition may be due to the internal cathode impedance of the tube. A response with a dip in the center indicates the opposite condition to that just described. In obtaining a flat-top response, the value of  $R_0$  is often a useful final adjustment. When a flat-top response is attained, it will be necessary to adjust the oscillator voltage for the correct  $A$  and bandwidth.

If the mixer tube is operated with a fairly large value of  $R_0$ , it is desirable to connect the suppressor to the cathode to prevent biasing of the suppressor grid. In the case of the 6SB7-Y and 6SA7 metal tubes, the suppressor is internally connected to the shell. Hence, the above connection leaves the shell "hot" for rf which is undesirable. The metal types can be made to operate satisfactorily but require a larger value of  $R_0$  than would be anticipated. For this reason, it is recommended that tubes be selected which do not have an internal suppressor-shell connection.

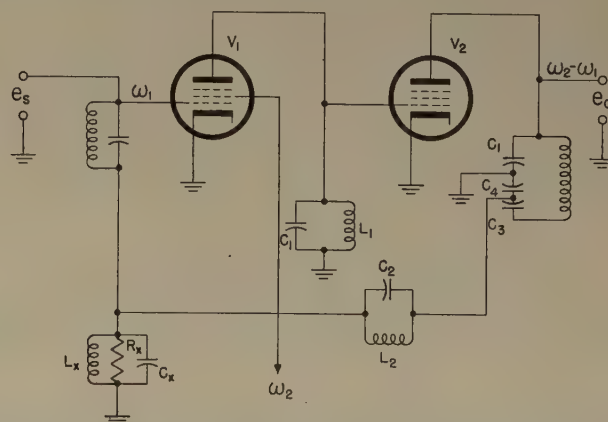


Fig. 10—Schematic diagram of reversed-phase mixer couple.

The above problems, as well as the local feedback at signal and oscillator frequency due to the large cathode impedance, may be eliminated by using the circuit arrangement shown in Fig. 10. In this case the phase of the output voltage is reversed in the output tank and the feedback is applied to the signal grid. The proper terminating impedance for the Beta circuit is provided by tuned circuit consisting of shunt connected  $L_x$ ,  $C_x$ , and  $R_x$ . Since this circuit must provide an essentially resistive termination over the IF pass band,  $Q_x \ll Q_2$ .  $R_x$  must be chosen such that it will present a sufficiently low impedance at the lowest signal frequency and at the same time allow practical realization of  $Z_2$ . The analysis of this circuit is identical to the preceding case, allowing for the voltage loss at the output tank.

# Mutual Coupling of a Slot with a Dipole Antenna\*

WALTER J. SURTEES†, MEMBER, IRE

**Summary**—A parameter is defined from which may be obtained the mutual coupling between a radiating slot, cut in a plane perfectly-conducting sheet, and a dipole fed at its base on the conducting plane. Using a slot cut in a sheet of copper and fed by a waveguide, experimental values of this parameter were obtained for various positions of the dipole relative to the slot. These values are plotted and compared with the theoretical ones, very good agreement being obtained.

## I. INTRODUCTION

THE THEORY of slots cut in rectangular waveguides has been treated elsewhere.<sup>1-3</sup> Recently, papers dealing with slots cut in a plane, perfectly-conducting sheet have been published.<sup>4-7</sup> Values for the input admittance of the slot agree for these cases, assuming the slot is narrow, its length is almost a half-wavelength, the field in the slot is transverse to the long dimension and varies sinusoidally along the slot, the sheet is perfectly-conducting and infinitely thin, and the face containing the slot is an infinite plane.

A slot in a waveguide may be made to radiate by inserting a probe in the guide near the slot. The probe may also act as an antenna to control the radiation pattern. The effect of the probe may be analyzed by considering an infinite set of images of the array and computing the coupling of all the images to the slot. Since the two nearest images will be about one-half and one wavelength from the slot, the mutual is not great and a good first approximation will be obtained by taking only the coupling between one slot and one dipole.

This paper gives an account of how this coupling may be determined when the dipole is thin, and with the same assumptions for the slot and sheet as indicated above.

## II. DEVELOPMENT OF THEORY

Consider an infinite, perfectly-conducting sheet coinciding with the  $XZ$  plane of a rectangular co-ordinate

system. There is a slot of length  $2L_1$  along the  $Z$ -axis whose width is  $2a$  (see Fig. 1). If  $2a$  is small compared with the wavelength and with the length of the slot, the electric field distribution along the slot can be assumed to be sinusoidal. By using Babinet's Principle<sup>8</sup> and using the field equations for the complementary dipole (see Brown),<sup>9</sup> the field components, at a point  $P$ , for a thin, center-fed slot of arbitrary length are as follows:

$$H_z = \frac{-jV_1}{2\pi Z_0 \sin kL_1} \left[ \frac{\exp(-jkr_1)}{r_1} + \frac{\exp(-jkr_2)}{r_2} - \frac{2 \exp(-jkr_0)}{r_0} \cos kL_1 \right] \quad (1a)$$

$$H_\rho = \frac{jV_1}{2\pi Z_0 \rho \sin kL_1} \left[ \frac{(z - L_1)}{r_1} \exp(-jkr_1) + \frac{(z + L_1)}{r_2} \exp(-jkr_2) - \frac{2z}{r_0} \exp(-jkr_0) \cos kL_1 \right] \quad (1b)$$

$$E_\phi = \frac{-jV_1}{2\pi \rho \sin kL_1} [\exp(-jkr_1) + \exp(-jkr_2) - 2 \exp(-jkr_0) \cos kL_1] \quad (1c)$$

Where

$Z_0 = 120\pi$  ohms, the impedance of free space,

$V_1$  = the voltage difference between the edges of the slot, at its center,

$k = 2\pi/\lambda = \omega/c$ ,

$\omega$  = applied angular frequency,

$r_1, r_2, r_0, z, \rho, \phi$  are as defined in Fig. 1.

All the components are to be multiplied by the time factor  $\exp(j\omega t)$ .

Now consider a dipole antenna of length  $L_2$ , parallel to the  $Y$ -axis, mounted at the point  $(z, d)$  on the plane sheet. The component of electric field intensity along it is  $E_\phi \cos \phi$ , where  $E_\phi$  is given by (1c). This field will induce a current along the length of the dipole.

The configuration may be considered as a four terminal network.<sup>10</sup> Let the slot be fed at terminals 1-1, and the dipole at terminals 2-2.  $V_1$  and  $V_2$  are the applied voltages at these terminals, and cause currents  $I_1$  and

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<sup>1</sup> A. F. Stevenson, "Theory of slots in rectangular waveguides," *Jour. Appl. Phys.*, vol. 19, pp. 24-38; January, 1948.

<sup>2</sup> W. H. Watson, "Waveguide Transmission and Antenna Systems," Oxford Univ. Press, London, England; 1947.

<sup>3</sup> A. L. Cullen, "Laterally-displaced slot in rectangular waveguide," *Wireless Eng.*, vol. 26, pp. 3-10; January, 1949.

<sup>4</sup> J. L. Putnam, B. Russell, W. Walkinshaw, "Field distribution near a centre-fed half-wave radiating slot," *Jour. IEE*, vol. 95, pp. 282-289; July, 1948.

<sup>5</sup> J. L. Putnam, "Input impedances of centre-fed slot aerials," *Jour. IEE*, vol. 95, pp. 290-294; July, 1948.

<sup>6</sup> J. W. Crompton, "Impedance characteristics of some slot aerials," *Jour. IEE*, vol. 97, pp. 39-44; January, 1950.

<sup>7</sup> N. A. Begovich, "Slot radiators," *Proc. I. R. E.*, vol. 38, pp. 803-806; July, 1950.

<sup>8</sup> H. G. Booker, "Slot aerials and their relation to complementary wire aerials," *Jour. IEE*, vol. 93, pp. 620-626; 1946.

<sup>9</sup> G. H. Brown, "Directional antennas," *Proc. I. R. E.*, vol. 25, pp. 78-145; January, 1937.

<sup>10</sup> E. C. Jordan, "Electromagnetic Waves and Radiating Systems," Prentice-Hall, Inc., New York, N. Y., pp. 347 ff.; 1950.

$I_2$  to flow. Then, following the notation of Guillemin,<sup>11</sup> the general mesh equations are:

$$I_1 = g_{11}V_1 + g_{12}I_2 \quad (2a)$$

$$V_2 = g_{21}V_1 + g_{22}I_2. \quad (2b)$$

Now:

$$g_{12} = -g_{21},$$

$g_{11}$  = admittance at terminals 1-1 when 2-2 are opened,

$g_{22}$  = impedance at terminals 2-2 when 1-1 are shorted.

If the slot and dipole are not too near, then approximately:

$$\left. \begin{aligned} g_{11} &= Y_{11}, \text{ the self-admittance of the slot alone,} \\ g_{22} &= Z_{22}, \text{ the self-impedance of the dipole alone.} \end{aligned} \right\} \quad (3)$$

When the dipole is not directly excited but the slot is,  $V_2 = 0$ ; then from (2),  $Y_1^{-1}$ , the slot input impedance is:

$$Y_1 = \frac{I_1}{V_1} = Y_{11} + \frac{(g_{21})^2}{Z_{22}}. \quad (4)$$

Applying the reciprocity theorem in a manner similar to Jordan,<sup>11</sup> the mutual coupling coefficient  $g_{21}$ , referred to the feed terminals is

$$g_{21} = \frac{j}{2\pi \sin kL_1 \sin kL_2} \int_0^{L_2} [\exp(-jkr_1) + \exp(-jkr_2) - 2 \cos kL_1 \exp(-jkr_0)] \frac{\cos \phi}{\rho} \sin k(L_2 - y) dy. \quad (5)$$

In the analytic and experimental work,  $L_1$  and  $L_2$  where chosen to be resonant. Thus, (5) becomes:

$$g_{21} = \frac{j}{2\pi} \int_0^{\lambda/4} [\exp(-jkr_1) + \exp(-jkr_2)] \cdot (\cos \phi / \rho) \cos ky dy. \quad (6)$$

On carrying out the integration, the following equation for  $g_{21}$  is obtained. (See Appendix for details).

$$\begin{aligned} g_{21} = \frac{j}{8\pi} & \{ \exp(kd) \{ \exp(jkz) [Ei(W_{23}) - Ei(W_{11}) \\ & + Ei(W_{22}) - Ei(W_{32})] \\ & + \exp(-jkz) [Ei(W_{21}) - Ei(W_{31}) \\ & + Ei(W_{24}) - Ei(W_{12})] \} \} \\ & - \exp(-kd) \{ \exp(jkz) [Ei(W_{53}) - Ei(W_{41}) \\ & + Ei(W_{52}) - Ei(W_{62})] \\ & + \exp(-jkz) [Ei(W_{51}) - Ei(W_{61}) \\ & + Ei(W_{54}) - Ei(W_{42})] \} \}. \end{aligned} \quad (7a)$$

where:

$$W_{11} = kd + jk(R_1 - 2L + z),$$

$$W_{12} = kd + jk(R_2 - 2L - z),$$

$$W_{21} = kd + jk(R_1 - z),$$

$$W_{22} = kd + jk(R_2 + z),$$

$$W_{23} = kd + jk(R_1 + z),$$

$$W_{24} = kd + jk(R_2 - z),$$

$$W_{31} = kd + jk(R_1 + 2L - z),$$

$$W_{32} = kd + jk(R_2 + 2L + z),$$

$$W_{41} = -kd + jk(R_1 - 2L + z),$$

$$W_{42} = -kd + jk(R_2 - 2L - z),$$

$$W_{51} = -kd + jk(R_1 - z),$$

$$W_{52} = -kd + jk(R_2 + z),$$

$$W_{53} = -kd + jk(R_1 + z),$$

$$W_{54} = -kd + jk(R_2 - z),$$

$$W_{61} = -kd + jk(R_1 + 2L - z),$$

$$W_{62} = -kd + jk(R_2 + 2L + z),$$

$$R_1 = (d^2 + 2L^2 - 2Lz + z^2)^{1/2},$$

$$R_2 = (d^2 + 2L^2 + 2Lz + z^2)^{1/2},$$

$$j = (-1)^{1/2}, k = 2\pi/\lambda, L = \lambda/4,$$

$$\lambda = \text{wavelength},$$

$d$  and  $z$  are distances giving the position of the dipole relative to the slot (see Fig. 1),

$$Ei(W) = \int_W^\infty [\exp(-v)/v] dv, \text{ the exponential integral of complex argument.}$$

When the dipole is located on the  $X$ -axis, that is, at a point along a line bisecting the length of the slot such that  $z=0$ , (6) becomes

$$g_{21} = \frac{j}{\pi} \int_0^{\lambda/4} \{ [\exp(-jkr_1) \cos \phi \cos ky] / \rho \} dy. \quad (8)$$

Either integrating this expression, or setting  $z=0$  in (7), the following is obtained

$$\begin{aligned} g_{21} = \frac{-j}{4\pi} & \{ \exp(kd) [Ei(W_1) - 2Ei(W_2) + Ei(W_3)] \\ & - \exp(-kd) [Ei(W_4) - 2Ei(W_5) + Ei(W_6)] \} \end{aligned} \quad (9a)$$

where

$$W_1 = kd + jk(R - 2L),$$

$$W_2 = kd + jkR,$$

$$W_3 = kd + jk(R + 2L),$$

$$W_4 = -kd + jk(R - 2L),$$

$$W_5 = -kd + jkR,$$

$$W_6 = -kd + jk(R + 2L),$$

$$R = (d^2 + 2L^2)^{1/2}.$$

### III. BASIS FOR EXPERIMENTAL METHOD

Babinet's Principle<sup>8</sup> can be applied to establish a relationship between the self-admittance,  $Y_{11}$ , of a slot and the self-impedance,  $Z_{22}$ , of its complementary dipole. It is

$$Z_{22} = Y_{11}(Z_0/2)^2 \quad (10)$$

where,  $Z_0$  is the impedance of free space.

<sup>11</sup> E. A. Guillemin, "Communication Networks," vol. II, p. 137, John Wiley and Sons, New York, N. Y.; 1935.

Now, (4) may be rearranged to give

$$(g_{21})^2 = Y_{11}Z_{22}[(Y_i/Y_{11}) - 1]. \quad (11)$$

The self-impedance of a quarter-wavelength, grounded dipole is known to be about 36.6 ohms, resistive. So that  $Y_{11}$ , the self-admittance of a half-wavelength slot radiating on one side of a conducting plane, may be obtained from (10) and substituted into (11). The ratio  $Y_i/Y_{11}$  may be obtained directly from measurements of the electric field standing wave ratios for the input admittance  $Y_i$  of the slot with the dipole present, and the input admittance  $Y_{11}$  of the slot with the dipole absent.

#### IV. DESCRIPTION OF EXPERIMENTAL METHOD AND EQUIPMENT

The experimental equipment used was the following. A 5,800 to 7,500 mc klystron oscillator, with its associated power supply and modulator, was employed as the signal source. The output was fed into standard  $1\frac{1}{2}$  by  $\frac{3}{4}$  inch waveguide. A variable attenuator, wave-meter, slotted section with tunable probe, and a standard standing wave meter were also used. The final section of the waveguide was soldered to the center of a four foot square copper sheet. A slot 2.10 centimeters in length and 0.1 centimeter in width, symmetrically located with respect to the walls of the waveguide, was cut in the copper sheet. In order to mount the dipole, small holes were drilled in the sheet at about one-sixteenth wavelength spacings on two lines, corresponding to the X-axis and the line  $z$ , as shown in Fig. 1.

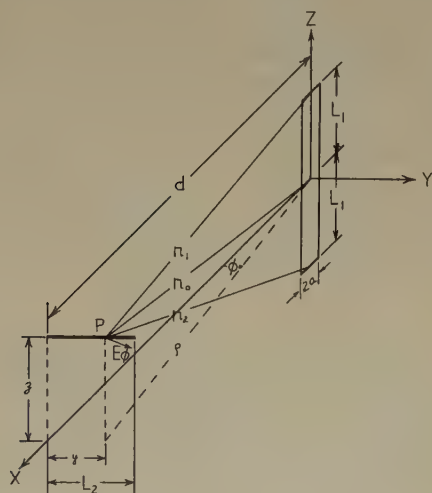


Fig. 1—Co-ordinate system for a slot of length  $2L_1$ , cut in an infinite-conducting plane coinciding with  $Y=0$ , and a dipole of length  $L_2$  fed from this plane.

The frequency at which the input impedance of the slot was purely resistive, was found. The source frequency was varied and the standing wave ratio in the waveguide, as well as the shift in the minimum, when the slot was completely short-circuited, were observed. The resonant frequency of the slot was 6,732 mc. At this frequency, the slot length was about 0.47 wave-

lengths, which agrees favorably with the value given by Putnam<sup>5</sup> and Crompton.<sup>6</sup> The oscillator was set at this frequency and the standing wave ratios and the positions of the minima were then measured for a thin dipole, half the length of the slot, mounted at different positions on the conducting sheet. Measurements were repeated with dipoles of slightly longer length, and dipoles having diameters of one-half and one and one-half times the width of the slot.

#### V. EXPERIMENTAL RESULTS

From the measured standing wave ratios and the positions of the electric field minima, the ratio  $Y_i/Y_{11}$ , for different values of  $d$  and  $z$ , was found. These values were inserted in (11) and  $g_{21}$  was computed. The theoretical values were obtained from (7) and (9). All these results are plotted in Fig. 2 and Fig. 3. It appears that the value of  $g_{21}$  determined experimentally is the same as that determined from theoretical considerations, within the limits of experimental error.

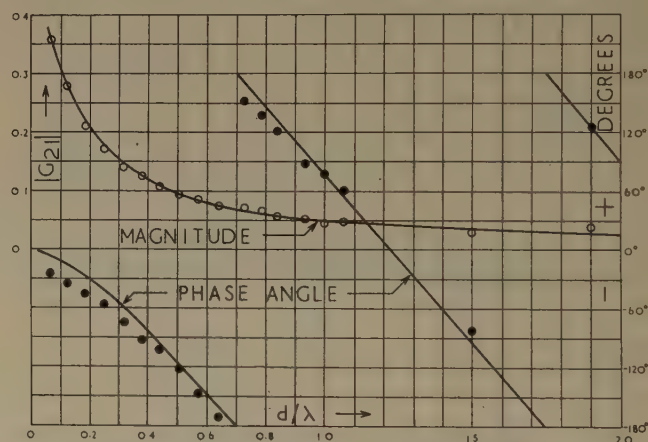


Fig. 2—Magnitude and phase angle of the mutual coupling parameter  $g_{21}$ , for  $z=0$ , as a function of spacing  $d/\lambda$ .  
— Theoretical values,  
○, ● experimental values for the magnitude and phase angle, respectively.

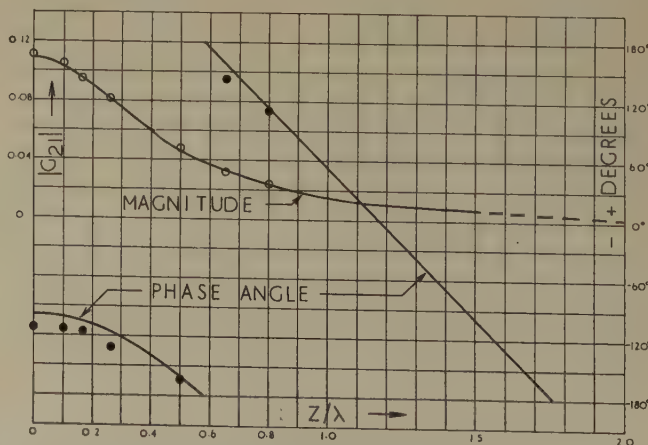


Fig. 3—Magnitude and phase angle of the mutual coupling parameter  $g_{21}$ , for  $d=0.44\lambda$ , as a function of  $z/\lambda$ .  
— Theoretical values,  
○, ● experimental values for the magnitude and phase angle, respectively.

For positions of the dipole at large distances from the slot, the absolute value of  $g_{21}$  approaches zero. This is to be expected, since the field from the slot falls off with distance from the slot, the induced current along the dipole will decrease with an increase in spacing. Thus the input admittance of the slot is only its self-admittance in the limit as  $d$  becomes very large, (see (4)).

Measurements were made with the dipole placed inside the slot opening. With a thick dipole, the slot was short-circuited; when the dipole was thin, the absolute value of  $g_{21}$  was approximately 0.48. This was lower than expected, thus showing that the voltage distribution along the slot was disturbed.

The error in the measured values of the imaginary component of  $g_{21}$  compared to the value obtained from theory, for close spacings, is analogous to the error in predicting accurately, by the "induced emf method," the reactive component of the self-impedance of an antenna which is assumed infinitely thin.

No noticeable differences in the results were seen when the diameter of the dipole was increased or decreased by one-half. When the length of the dipole was increased slightly, the change to  $g_{21}$  was very small, but it indicated that a small reactive component was added to the value of  $Z_{22}$ .

## VI. CONCLUSIONS

Since the theory has been developed for infinitely thin slot and dipole antennas, any application, for example, the possibility of controlling the radiation pattern of slot antennas, will be limited to very thin antennas. For a slot cut in the wall of a waveguide, some error would be made due to the thickness of the walls and due to the face containing the slot being finite and not infinite planes as considered here.

## VII. ACKNOWLEDGMENT

The author wishes to express his appreciation for the support extended by the Defence Research Board of Canada, and for facilities given by the Department of Electrical Engineering, University of Toronto, without which this paper would not have been possible. Also, appreciation is extended to Professor George Sinclair of the University of Toronto for his aid and assistance, to John H. Craven for his aid in parts of the experimental work, and to James Wilbur who carried out some of the necessary computations.

## APPENDIX

### Evaluation of the Mutual Parameter $g_{21}$

From (6), the expression for the mutual parameter is:

$$g_{21} = \frac{j}{2\pi} \int_0^{\lambda/4} [\exp(-jk r_1) + \exp(-jk r_2)] (\cos \phi / \rho) \cos ky \, dy,$$

where:

$$\begin{aligned} \cos \phi &= d/\rho, \quad \rho^2 = d^2 + y^2, \\ r_1^2 &= \rho^2 + (L - z)^2, \quad r_2^2 = \rho^2 + (L + z)^2. \end{aligned}$$

$L$  = half length of the slot =  $\lambda/4$ ,

$d$  and  $z$  determine spacing of the slot and dipole,

$y$  = distance along the dipole.

Now replace  $\cos ky$  by  $1/2 [\exp(jky) + \exp(-jky)]$ , and note that

$$\begin{aligned} \frac{1}{\rho^2} &= \frac{1}{r^2 - (L - z)^2} = \frac{1}{2r(r + [L \mp z])} \\ &+ \frac{1}{2r(r - [L \pm z])}, \end{aligned}$$

where the upper sign before  $z$  is taken when  $r = r_1$ , and the lower sign is taken when  $r = r_2$ . Thus  $g_{21}$  becomes the sum of eight integrals. A typical integral is the following:

$$J_2 = \frac{jd}{4\pi} \int_0^{\lambda/4} \frac{\exp(-jk[r_1 - y]) \, dy}{2r_1(r_1 - L + z)}.$$

Let  $u^2 = d^2 + (L - z)^2$ , then,  $r_1^2 = u^2 + y^2$ .

Changing the variable to  $s$ , by letting  $us = r_1 - y$ , and  $u/s = r_1 + y$ , and substituting into  $J_2$ , a new form is obtained. Expanding the denominator in partial fractions and letting

$$w = s - b, \quad \text{and} \quad v = s - c,$$

where,

$$b = \frac{1}{u} (L - z + jd), \quad \text{and} \quad c = \frac{1}{u} (L - z - jd),$$

the following is obtained,

$$\begin{aligned} J_2 &= \frac{1}{8\pi} \left\{ -\exp(-jkub) \int_{W_{71}}^{W_{11}} [\exp(-w)/w] \, dw \right. \\ &\quad \left. + \exp(-jkuc) \int_{W_{81}}^{W_{41}} [\exp(-v)/v] \, dv \right\}. \end{aligned}$$

The limits  $W_{11}$  and  $W_{41}$  have the same values as those given in (7b).  $W_{71}$  and  $W_{81}$  have not been defined as they cancel in the final expression for  $g_{21}$ .

Thus, using the above results, and employing similar transformations to the remaining integrals in the expression for  $g_{21}$ , the value for this parameter as given by (7a) is obtained.



# 1952 IRE National Convention Program

WALDORF-ASTORIA HOTEL and GRAND CENTRAL PALACE—MARCH 3-6

## Registration

Members and visitors may register at either the Waldorf-Astoria Hotel or Grand Central Palace at the following hours:

### Waldorf-Astoria

### Grand Central Palace

Mon. 9 A.M.—5 P.M. 11:00 A.M.—9 P.M.  
Tue. 9 A.M.—8 P.M. 9:30 A.M.—9 P.M.  
Wed. 9 A.M.—6 P.M. 9:30 A.M.—6 P.M.  
Thur. 9 A.M.—1 P.M. 9:30 A.M.—9 P.M.

## Technical Sessions

Over 200 technical papers will be presented in 43 sessions. A schedule of sessions is listed below; 100-word summaries of papers appear in the following pages.

## Exhibits

The Radio Engineering Show, featuring 347 engineering exhibits, will occupy four floors of Grand Central Palace. A list of exhibitors and their products starts on page 1A of this issue. Exhibits will be open during the Palace registration hours noted above.

## Principal Events

The **Annual Meeting**, to be held at 10:30 A.M. on Monday in the Jade Room of the Waldorf, is for the entire membership. It will feature a novel presentation of 40 years of IRE by Alfred N. Goldsmith and John V. L. Hogan, two of the co-founders, entitled "The IRE: From Acorn to Oak."

A "get-together" **Cocktail Party** will be held on Monday evening from 5:30 to 8:00

in the Grand Ballroom of the Waldorf. Tickets may be purchased at \$3.80 each.

The **President's Luncheon**, on Tuesday at 12:45 P.M. in the Starlight Roof of the Waldorf, will honor IRE President Donald B. Sinclair. Special tables will be reserved for Professional Group members. Tickets are available at \$5.75 each.

The **Annual Banquet**, to be held in the Grand Ballroom at 6:45 P.M. on Wednesday, will feature a major address by Charles E. Wilson, Director of Defense Mobilization. The 1952 IRE awards will be presented at this time. Tickets are on sale at \$12.00 each.

An outstanding **Women's Program** of tours and shows has been arranged for the four days. Women's registration begins at 9:30 A.M. on Monday in the East Foyer of the Waldorf.

## SCHEDULE OF TECHNICAL SESSIONS\*

BELMONT-PLAZA		WALDORF-ASTORIA			GRAND CENTRAL PALACE	
	Moderne Room	Grand Ballroom	Astor Gallery	Jade Room	Maroon Room	Blue Room
Mon. P.M. 2:30-5	Symposium: Subaudio Instru- mentation (1-5)	Symposium: Management of Research and De- velopment (6-9)	Symposium: Transistor Circuits (10-13)	Information The- ory I—Coding Procedures (14-18)	Audio (19-23)	Symposium: New Developments in Telemetering (24-28)
Tues. A.M. 10-12:30	Instrumentation I—High-Frequency Instrumentation (29-33)	Television I— General A (34-37)	Circuits I (38-42)	Information The- ory II—Noise Sta- tistics and Signal Detection (43-47)	Microwaves I— Waveguides A (48-52)	Symposium: Television Broad- casting; Audio and Video Systems (53-57)
Tues. P.M. 2:30-5	Instrumentation II—Electronic Measurements A (58-62)	Television II— Color (63-67)	Circuits II and In- formation Theory III (68-74)	Medical Electron- ics (75-80)	Microwaves II— Waveguides B (81-85)	Symposium: Television Station Construction and Theater Conversion (86-89)
Tues. Eve. 8-10:30		Special Symposium: Present Status of NTSC Color Tele- vision Standards (90)				
Wed. A.M. 10-12:30	Instrumentation III—Electronic Measurements B (91-95)	Television III— General B (96-100)	Circuits III (101-106)	Propagation (107-111)	Microwaves III— Filters and Cir- cuits (112-116)	Symposium: Digital Computers in Control Systems (117-121)
Wed. P.M. 2:30-5	Antennas I— General (122-126)	Symposium: UHF Receivers I (127-132)	Circuits IV (133-138)	Electron Tubes I— Power Output and Gas Tubes (139-143)	Radar and Radio Navigation (144-148)	Symposium: Magnetic Core Memory Devices for Digital Com- puters (149-153)
Thurs. A.M. 10-12:30	Antennas II— Microwave A (154-158)	Symposium: UHF Receivers II (159-162)	Feedback Control (163-167)	Electron Tubes II—Small High- Frequency Tubes (168-172)	Symposium: The Integration of Electronic Equip- ment with Air- frame Design (173-176)	Digital Computers (177-181)
Thurs. P.M. 2:30-5	Antennas III— Microwave B (182-186)	Radio Communi- cation Systems (187-191)	Circuits V (192-198)	Electron Tubes III—Cathode-Ray Tubes (199-203)	Symposium: What's New in Mobile Radio (204-207)	Symposium: Reliability of Mi- litary Electronic Equipment (208-211)

\* Numbers in parenthesis following session titles refer to summaries of technical papers on the following pages.

## SUMMARIES OF TECHNICAL PAPERS

## Note

No papers are available in preprint or reprint form nor is there any assurance that any of them will be published in the PROCEEDINGS OF THE I.R.E., although it is hoped that many of them will appear in these pages in subsequent issues.

## SYMPOSIUM

## Subaudio Instrumentation

(Organized by Professional Group on Instrumentation)

Chairman, ERNST WEBER

(Polytechnic Institute of Brooklyn, Brooklyn, N. Y.)

This symposium will include five papers by workers in the subaudio field and a subsequent round-table discussion. The papers describe instruments for measurements of physical motion and associated electrical signals. Methods of analysis and synthesis as applied to the subaudio frequency range will also be covered. The papers and discussion will stress both available instrumentation and the need for new methods and equipment.

## 1. DIRECT SYNTHESIS APPLIED TO SUBAUDIO FREQUENCY SYSTEMS

J. R. MOORE

(North American Aerophysics Laboratory, Downey, Calif.)

## 2. GENERATING EQUIPMENT FOR SUBAUDIO FREQUENCIES

E. H. GAMBLE

(Curtiss-Wright Corporation, Carlstadt, N. J.)

## 3. SUBAUDIO FREQUENCIES IN PETROLEUM EXPLORATION

W. M. RUST, JR.

(Humble Oil and Refining Company, Houston, Tex.)

## 4. OSCILLOGRAPHIC INSTRUMENTATION FOR THE SUBAUDIO FIELD

P. S. CHRISTALDI

(Allen B. DuMont Laboratories, Clifton, N. J.)

## 5. INSTRUMENTATION FOR HIGH-POWER HYDRAULIC SERVO DEVELOPMENT

HAROLD GOLD

(NACA, Lewis Propulsion Laboratory, Cleveland, Ohio)

## SYMPOSIUM

## Management of Research and Development

(Organized by Professional Group on Engineering Management)

Chairman, W. L. EVERITT

(University of Illinois, Urbana, Ill.)

A panel composed of representatives with broad backgrounds of experience and accomplishments in research and development activities will discuss their philosophies of the management of research and development activities. Following the presentation of the papers the audience will be invited to participate with questions and comments. Panel members presenting papers are:

6. W. R. G. BAKER (General Electric Company, Syracuse, N. Y.)

7. R. D. BENNETT (U. S. Navy Ordnance Laboratory, White Oak, Silver Springs, Md.)

8. G. N. THAYER (Bell Telephone Laboratories, Inc., Murray Hill, N. J.)

9. R. I. COLE and O. G. TALLMAN (Griffiss Air Force Base, Rome, N. Y.)

## SYMPOSIUM

## Transistor Circuits

(Organized by Professional Group on Circuit Theory)

Chairman, C. H. PAGE

(National Bureau of Standards, Washington, D. C.)

This symposium will present a survey of transistor circuits particularly designed to illustrate new aspects of circuit analysis resulting from the use of these elements.

## 10. TRANSISTOR OPERATION: ELEMENTS

(a). EQUIVALENT CIRCUITS

J. A. MORTON

(Bell Telephone Laboratories, Murray Hill, N. J.)

(b). PARAMETER MEASUREMENT

V. P. MATHIS

(General Electric Company, Syracuse, N. Y.)

(c). STABILIZATION OF OPERATING POINTS

R. F. SHEA

(General Electric Company, Syracuse, N. Y.)

## 11. TRANSISTOR BAND-PASS AMPLIFIERS

R. P. MOORE

(Radio Corporation of America, Camden, N. J.)

## 12. TRANSISTOR OSCILLATORS

J. S. SCHAFFNER

(General Electric Company, Syracuse, N. Y.)

## 13. TRANSISTOR PULSE CIRCUITS

J. H. FELKER

(Bell Telephone Laboratories, Whippany, N. J.)

## Information Theory I—Coding Procedures

Chairman, M. J. E. GOLAY

(Signal Corps Engineering Laboratories, Fort Monmouth, N. J.)

## 14. EFFICIENT CODING

B. M. OLIVER

(Bell Telephone Laboratories, Inc., Murray Hill, N. J.)

Modern communication theory has shown that the only way to reduce the channel capacity (loosely, the bandwidth) required for electrical messages, is to translate them into a language (signal) in which the successive symbols (sample amplitudes) are more nearly independent of one another, and in which the different symbols (sample amplitudes) are used with nearly equal probability. In this way all the possible waveforms which the channel can handle (with a given peak power) become useful in that they now all represent possible messages.

This paper will present several possible methods of achieving such a translation, or coding, of signals.

## 15. TELEVISION SIGNAL STATISTICS

E. R. KRETZMER

(Bell Telephone Laboratories, Inc., Murray Hill, N. J.)

Practical attempts at television bandwidth reduction require a knowledge of the picture signal statistics, such as signal amplitude distribution and autocorrelation. These two functions have been measured for a number of typical television pictures. Amplitude distributions have been determined also for error signals resulting from various types of linear prediction. Autocorrelation has been measured both along the scanning lines and at various angles with these lines.

Typical results of these measurements will be presented. They give us a fair idea of the bandwidth compression theoretically achievable (through reduction of channel capacity required) by means of linear decorrelation.

## 16. CODING WITH LINEAR SYSTEMS

J. P. COSTAS

(General Electric Company,  
Syracuse, N. Y.)

Message transmission over a noisy channel is considered. Two linear networks are to be used; one at the sending end for treatment of the message before transmission and the second network at the receiving end of the channel for message recovery. For a given allowable average signal power and for a specified channel noise, a design method is developed which yields optimum coding and decoding networks. Special cases of the design equations are shown to yield the Optimum Filter Formula of Wiener and the Optimum Compensator Formula of Lee. The results of a numerical example are given and discussed.

## 17. PREDICTIVE CODING

PETER ELIAS

(Harvard University, Cambridge, Mass.)

Predictive coding is a method for coding message terms, in which the transmitter and the receiver store past message terms, and from them estimate the value of the next term. The transmitter codes the difference between the message term and its predicted value, and transmits this coded "error." The receiver decodes the error term and adds it to its prediction, reproducing the correct message term.

This coding procedure is compared with Shannon-Fano ideal coding methods. A criterion for the selection of predictors for predictive coding is given, and the use of Wiener's optimum linear predictor is discussed.

## 18. EXPERIMENTS WITH LINEAR PREDICTION IN TELEVISION

C. W. HARRISON

(Bell Telephone Laboratories, Inc.,  
Murray Hill, N. J.)

The correlation present in a signal makes possible the prediction of the future of the signal in terms of the past and present. Linear prediction, although it does *not* make full use of the past, is nevertheless remarkably effective with certain signals, and is also appealing because of its relative simplicity. Here the prediction for the next signal sample is simply the sum of previous signal samples each multiplied by an appropriate weighting factor.

This paper will describe the apparatus used for some experiments on linear prediction of television signals, and will discuss the results obtained to date.

## Audio

Chairman, L. L. BERANEK

(Massachusetts Institute of Technology,  
Cambridge, Mass.)

## 19. MICROPHONES FOR THE MEASUREMENT OF SOUND PRESSURE LEVELS OF HIGH INTENSITY OVER WIDE FREQUENCY RANGES

J. K. HILLIARD

(Altec Lansing Corporation,  
Beverly Hills, Calif.)

This paper describes measurements and transmission of sound pressure levels of very high intensities in the subaudible, audible, and super audible ranges. In some cases the Altec standard 21B microphone is used, and for the extremely high intensities a modified type is used. These microphones will withstand high ambient temperatures. They may be used directly in the sound field or with probe tubes. They are used to measure blasts in excess of one atmosphere. Photographs of waveforms on blasts up to an intensity of 202 db, reference 0.0002 dynes per square centimeter, will be shown, at which point the open circuit output is approximately 100 volts. This output corresponds to a voltage ratio of  $10^{10}$  times the minimum intensity which the human ear can detect.

## 20. AN INSTRUMENT FOR MEASURING THE TIME-DISPLACEMENT ERROR OF RECORDERS

E. N. DINGLEY, JR.

(Armed Forces Security Agency,  
Washington 25, D. C.)

There is described an instrument designed to provide a graphic record of the time variation of the time-displacement error of sonic recording-reproducing equipment. The utility of this instrument for measuring per cent flutter and flutter index is discussed.

## 21. A METHOD FOR MEASURING THE CHANGES INTRODUCED IN RECORDED TIME INTERVALS BY A RECORDER-REPRODUCER

J. F. SWEENEY

(Armed Forces Security Agency,  
Washington 25, D. C.)

Recorders are being increasingly used in instrumentation problems where the recorded information is in the form of a sequence of time intervals. In order to evaluate the suitability of various recording equipments for these applications, a technique has been developed for measuring the changes introduced in recorded time intervals by the recorder. By the use of this technique, a continuous permanent graph is produced of the variations in recorded time intervals introduced by the recording equipment. This graph may also be used to find the instantaneous frequency deviation, flutter repetition rates, and flutter wave shapes.

## 22. APPLICATION OF ELECTRIC CIRCUIT ANALOGIES TO LOUDSPEAKER PROBLEMS

B. N. LOCANTHI

(California Institute of Technology,  
Pasadena, Calif.)

Electric circuit analogies which describe the three major types of loudspeaker systems currently in use today will be discussed. These are: (1) direct radiator in an infinite baffle; (2) direct radiator in a reflex enclosure, including the effect of the mutual impedance between the port and direct radiator on the radiating side of the enclosure; and (3) horn loudspeaker, treating the horn as a distributed parameter system.

Response curves obtained from the electric circuit analogies will be discussed showing the effects of amplifier source im-

pedance, electromechanical coupling coefficient, and diaphragm suspension compliance on efficiency and bandwidth.

## 23. A SOUND-SURVEY METER

ARNOLD PETERSON

(General Radio Company,  
Cambridge, Mass.)

A simple, compact, low-cost noise meter has been developed as a companion to high performance instruments for use by audio and acoustical engineers. Its performance closely approximates that of standard sound-level meters, but it has simplified operating features. The amplifier and metering circuit are stabilized by negative feedback, and a continuous level control is provided. Its diminutive size, good characteristics, ease of servicing, and simplicity of operation make it ideal for many applications, some of which are economically feasible only with such a low-cost instrument. Applications include sound system measurements, noise surveys, product noise measurement, and experiments in acoustics.

## SYMPOSIUM

### New Developments in Telemetry

(Organized by Professional Group on Radio Telemetry and Remote Control)

Chairman, C. H. HOEPPNER

(Raytheon Manufacturing Company,  
Waltham, Mass.)

The Symposium will deal with the problem of recording FM-FM telemetry signals on magnetic tape, and ways and means of compensating for and avoiding the errors introduced by even small values of flutter and drift which give trouble because of the 7.5 per cent deviation used. Other new developments will be discussed.

## 24. NEW DEVELOPMENTS IN TELEMETERING

C. H. HOEPPNER

(Raytheon Manufacturing Company,  
Waltham, Mass.)

The problems of storing and reproducing telemetered data are defined. The need for advances in recorders and error compensating systems is discussed and some new developments in this field are noted. Two general methods presently in use for processing telemetry data are outlined and the sources of error in each are discussed. The advantages of sampling and coding at various points in the system are considered.

## 25. RECENT ADVANCES IN MAGNETIC RECORDING FOR TELEMETERING APPLICATIONS

W. T. SELSTED

(Ampex Electric Corporation,  
Redwood City, Calif.)

The problem of recording FM-FM telemetry is stated. The development of a four-channel magnetic tape telemetry recorder with a peak-to-peak flutter of less than 0.1 per cent is described. Some other examples of special applications of magnetic tape recorders to recording telemetered data will also be described.

## 26. FAIRCHILD MODEL 150 TELE-METERING DATA RECORDER

C. F. KEZER

(Fairchild Recorder Equipment Company, Whitestone, N. Y.)

The design considerations of a new rack-mounted four-channel telemetering tape recorder suitable for FM-FM signals are discussed. Problems for which solutions are presented include: flutter of less than 0.1 per cent peak to peak; a speed control system which compensates for tape dimensional changes and other long-term speed variations from a signal recorded on the tape; multi-channel operation; 80 kc frequency response; and large tape reels. Methods of measuring flutter will also be described.

## 27. RECORDING TELEMETERING DATA

M. V. KIEBERT

(Bendix Research Laboratories, Detroit, Mich.)

The telemetering data recording system is analyzed in view of various instrumentation requirements. Four basic reasons for recording telemetering signals are defined: (1) data recording at locations not ordinarily requiring concurrent information presentations, (2) insurance against loss of information by concurrent presentation systems as a result of equipment failure or malfunction, (3) condensed data storage of information on high density media, and (4) concurrent transducer media for data reduction. Calibration curve compensator, and scale factor correction operating system are outlined and described. Typical records are shown and compared with concurrent presentation.

## 28. TELEMETERING BY PULSE-CODE MODULATION

B. D. SMITH

(Melpar Company, Alexandria, Va.)

The possibility of using pulse-code modulation in a radio telemetering system is considered. The basic methods of binary coding are considered and the methods which are most suited to an airborne telemeter are discussed. Quantization errors and methods of nonlinear quantization with the feedback type of coding are described. The advantages and disadvantages of pulse-code modulation over FM or other modulation systems are discussed with respect to a telemetering system in which automatic data reduction is contemplated. Methods of data recording and processing by means of ground equipment are discussed.

## Instrumentation I—High-Frequency Instrumentation

Chairman, I. G. WOLFF

(Radio Corporation of America, Princeton, N. J.)

## 29. VHF Q-MEASUREMENT TECHNIQUES

D. M. HILL

(Boonton Radio Corporation, Boonton, N. J.)

A Q-Meter covering the frequency range

20 to 260 mc will be described. An improved voltmeter circuit permits measurement of both low-Q and high-Q components and also enables small changes in Q to be measured more accurately. A new variable air condenser has been designed to reduce errors due to inductance and series resistance in the standard condenser.

Measurement techniques and errors due to circuit residuals and frequency effects will be discussed.

## 30. A HIGH SENSITIVITY METHOD FOR MEASURING CONDUCTANCE AND CAPACITANCE AT RADIO FREQUENCIES

W. C. FREEMAN, JR.

(Boonton Radio Corporation, Boonton, N. J.)

A new and more sensitive instrument for measuring conductance and capacitance at radio frequencies has been designed. Operating on the resonant circuit substitution principle, this Conductance Meter employs a calibrated dc variable resistance as the load of a diode rectifier connected across the resonant circuit. This provides an accurate substitution method for r.f. conductance with a direct-reading calibration which is independent of frequency. The capacitance substitution is provided by a precision variable capacitor designed to have low change of conductance with dial setting.

The sensitivity and stability requirements for the measurement of such high quality dielectrics as Polystyrene and Teflon are analyzed and the methods used to meet these requirements are described.

## 31. A MEAN-SQUARE VACUUM-TUBE VOLTMETER

L. A. ROSENTHAL AND G. M. BADOYANNIS  
(Rutgers University, New Brunswick, N. J.)

By means of a nonlinear resistor network it is possible to obtain an instantaneous "squarer," or the output current of the network is proportional to the instantaneous square of the input voltage. A dc ammeter in the output circuit indicates the average current which is directly proportional to the mean-square voltage. Upon combining the "squarer" with a preamplifier, a mean-square voltmeter results. There are no zero-setting or balancing controls and the output scale is linear in power and square-law in voltage. The squaring action is accurate to  $\pm 2.5$  per cent for a current range of 50 to 1, and the upper frequency limit is approximately 500 kc. As a voltmeter the circuit is useful in the study of complex waveforms, and as a squarer it can find interesting applications such as frequency doublers and simple computers.

The theory of operation, principles of design, performance data, and applications are discussed.

## 32. A NEW TECHNIQUE FOR THE EVALUATION OF LEAKAGE AND RADIATION FROM SIGNAL GENERATORS

W. A. STIRRAT

(Signal Corps Engineering Laboratories, Fort Monmouth, N. J.)

Heretofore, the procedure for evaluating tolerable leakage and radiation from signal generators has been of insufficient rigor and

has led to a very arbitrary establishment of allowable limits. An investigation recently concluded for the Signal Corps resulted in the establishment of those limits compatible with the conduction of tests on Army receivers.

However, the limits were given in terms of pick-up voltages which are of an extremely low order over certain frequencies of the spectrum and cannot readily be measured with any degree of accuracy.

Techniques have been evolved at SCEL which circumvent the difficulty of such measurement.

## 33. A WIDE-BAND SWEEP GENERATOR

F. P. BLECHER

(Polytechnic Research and Development Company, Inc., Brooklyn, N. Y.)

A wideband sweep generator is described which features a fundamental frequency coverage of 40 to 950 megacycles, one volt output, a minimum of ten megacycles sweep width, and provision for introducing an external marker. The instrument is completely shielded and employs a modified type of waveguide operating beyond cutoff attenuator which provides output voltages between one volt and ten microvolts. Over most of the frequency range, the sweep width is adjustable between zero and twenty megacycles with practically no change in the center frequency. The instrument may also be employed as a C.W. oscillator with low harmonic distortion over the entire frequency range.

Design specifications are discussed and the new techniques responsible for the special characteristics of the instrument are explained.

## Television I—General A

Chairman, A. V. LOUGHREN

(Hazeltine Electronics Corporation, Little Neck, N. Y.)

## 34. GAMMA CORRECTION IN COLOR TELEVISION

S. APPLEBAUM

(General Electric Company, Syracuse, N. Y.)

Gamma correction in color television is desirable to correct the tonal and chromaticity distortion which results from the use of nonlinear display tubes. Correction should be made at the transmitter in the primary colors of the receiver. A nonlinear color receiver causes some noise cross talk from the chromaticity channels to the luminance channel. Despite this, the over-all noise sensitivity is less than that of a linear color receiver. The effect of precorrection upon the nonlinear compatible monochrome picture is to linearize the tonal rendition but attenuate somewhat the display of saturated colors.

## 35. THE SPECIFICATION AND CORRECTION FOR NONLINEARITY OF CATHODE-RAY TUBES

R. C. MOORE

(Philco Corporation, Philadelphia, Pa.)

Correction for nonlinearity of cathode-ray tubes is particularly important in color television. The problems of interpreting

data on cathode-ray tube characteristics in order to specify a suitable corrector are considered. It is shown that exponent value of assumed power law is not critical.

The requirements on corrector circuits to satisfy a desired specification are considered. A particular circuit used in a laboratory color-signal source is described and its operating characteristics discussed. It is characterized by good performance and stability.

### 36. COLORIMETRIC MEASUREMENTS IN COLOR TELEVISION SYSTEM

S. W. MOULTON

(Philco Corporation, Philadelphia, Pa.)

A subjective type colorimeter is described that fulfills an increasingly important need for a method to measure quantitatively and simply the output of color television receivers. The spectral similarities of its two fields increases its accuracy and facilitates measurements. The question of the observer's spectral response is eliminated.

### 37. FRAME SYNCHRONIZATION FOR COLOR TELEVISION

DONALD RICHMAN

(Hazeltime Corporation, Little Neck, N. Y.)

The proposed NTSC standards for color television utilize the technique of color phase alternation wherein the phase sequence of color in the color subcarrier is reversed on alternate fields. An arrangement for automatically synchronizing the direction of reversing at the receiver and at the transmitter is desirable to its operation. It will be shown that the present monochrome FCC synchronizing waveform contains the necessary signal information for reliable frame synchronizing. This paper describes practical circuits for frame synchronization, and discusses theoretical considerations relating to the problem of frame synchronization.

## Circuits I

Chairman, H. J. CARLIN

(Polytechnic Institute of Brooklyn, Brooklyn, N. Y.)

### 38. NETWORK ALIGNMENT TECHNIQUE

J. G. LINVILL

(Massachusetts Institute of Technology, Cambridge, Mass.)

An experimental method by which variable components in a network can be adjusted to bring the frequency or time response of the network into correspondence with the response of a standard network will be described. The technique involves, first, consideration of the difference of the response of the network being adjusted from that desired, and second, consideration of the changes in response due to motions of the elements of a perfect network taken one at a time. The steps are so simple experimentally that not even a slide rule is required for the whole process. Experimental data and oscilloscope pictures will be presented.

### 39. NETWORK ANALYSIS BY A NEW SEMI-AUTOMATIC COMPUTER

R. L. BRIGHT AND G. H. ROYER

(Carnegie Institute of Technology, Pittsburgh, Pa.)

A new analog computer which yields directly the complex natural frequencies of any linear system and the locus of these natural frequencies as system parameters are varied is described. General theory details of a unit for linear systems up to the sixth order are discussed. The calculator also provides a very simple method of indicating the locus of the complex natural frequencies as any of the system parameters are varied. Using currents fed from a computer, natural frequency of the system is indicated by a servo-controlled probe whose co-ordinates are the values of the real and imaginary parts of a complex root of the system.

### 40. NETWORK ANALYSIS BY TWO NEW COMPUTERS

D. HERR

(Hughes Aircraft Company, Culver City, Calif.)

Two new economical analogue computers to be used as *desk-side tools* in the design and analysis of servomechanisms, networks, amplifiers, and analogous systems are described. In a certain sense the two computers are complementary in their use and with the use of a differential analyzer.

The first computer is a modern version of an algebraic-equation solver earlier described. The second computer is a mechanization of the "locus-of-roots" method of analysis and design previously explained by W. R. Evans. Each uses two new computer components: one a high-precision, universal-frequency ac induction resolver, and the other an ac induction potentiometer.

### 41. NETWORK RESPONSE CHARACTERISTICS USING THE COMPLEX PLANE SCANNER

J. R. RAGAZZINI AND G. REYNOLDS

(Columbia University, New York, N. Y.)

The complex plane scanner is an electronic analogue computer which electrically scans the complex plane by equivalently running a point along the imaginary axis. By multiplying voltages equivalent to the magnitudes of the distances, from the poles and zeros to the running point, the magnitude of the transmission is obtained. Multiplications and divisions are carried out with logarithmic networks, and the magnitude of the transmission in db is the magnitude of an ac voltage. If a perturbation is added, the phase slope of the transmission characteristic is obtained. The display of the complex plane scanner is by oscilloscope. Thickness of the curve is proportional to the phase slope.

### 42. RESONANCE CHARACTERISTICS BY CONFORMAL MAPPING

P. M. HONNELL AND R. E. HORN

(Washington University, St. Louis, Mo.)

The analytical expression  $f(\lambda) = a\lambda + b + c/\lambda = \sigma + j\omega$ , may be called the "resonance function" since it represents the impedance of the series-connected LRS circuit and the

admittance of the parallel-connected CGR circuit, among others. The conformal mapping of the  $\lambda$  plane onto the  $f(\lambda)$  plane yields a figure of considerable usefulness in clarifying the meaning of the generalized impedance of the series circuit and admittance of the parallel circuit for complex frequencies. This will be illustrated by typical examples, together with other applications of the figure to more general circuit configurations.

A brief discussion of the mapping of the reciprocal of the resonance function will be included for completeness.

## Information Theory II —Noise Statistics and Signal Detection

Chairman, A. G. CLAVIER

(Federal Telecommunications Laboratories, Inc., Nutley, N. J.)

### 43. DISCUSSION OF A METHOD OF EXPANDING NOISE AUTOCORRELATION FUNCTION IN A POWER SERIES

F. W. LEHAN

(California Institute of Technology, Pasadena, Calif.)

It is shown that under certain conditions the autocorrelation function of a random noise source may be expanded in the following power series:

$$\rho(\tau) = 1 - \frac{n^2(\pi\tau)^2}{2!} + \frac{(nn')^2(\pi\tau)^4}{4!} - \frac{(nn'n'')^2(\pi\tau)^6}{6!} + \dots$$

where

$n$  = the average rate of occurrence of zeros in the noise function

$n'$  = the average rate of zeros in the first derivative, etc.

The limitations and usefulness of this expansion are discussed.

### 44. A PROPOSAL FOR THE DETERMINATION OF COHERENCE IN A SIGNAL FIELD

B. S. MELTON

(Headquarters, U. S. Air Force, Washington, D. C.)

AND

P. R. KARR

(National Bureau of Standards, Washington, D. C.)

A simple statistical procedure, based on multiple coincidence of field polarities as indicated by several detectors, offers a criterion of the existence of a signal below the general noise level, the effectiveness of the procedure depending upon the signal duration. As an example, with six detectors in a field where there is a sine wave signal whose power is one-twelfth the noise power, there will be 80 per cent more polarity agreements than for the noise alone. A scheme is shown to illustrate how an electrical system can perform the analysis and present the results continuously.

**45. THE RESPONSE OF LINEAR SYSTEMS TO RANDOM NOISE**

B. GOLD

(Hughes Aircraft Company, Culver City, Calif.)

AND

J. P. RUINA

(Brown University, Providence, R. I.)

When random noise is suddenly applied to a linear system with  $N$  outputs, a complete description is obtained by means of an  $N$  dimensional probability distribution function. This function is in general time dependent and may or may not reach a stationary value.

In this paper formulas are derived, with the aid of circuit theory concepts, with which one can obtain all the (co)variances of the desired distribution as functions of time. In the steady state ( $t \rightarrow \infty$ ) the results obtained become the well-known results for the stationary output of a linear system with input noise.

The method is applied to several problems.

**46. CORRELATOR FOR LOW FREQUENCIES**

V. J. GUETHLEN

(Goodyear Aircraft Corporation, Akron, Ohio)

A number of electronic correlators capable of performing the necessary mathematic operations to obtain correlation functions have been reported on in the past. In general, existing electronic correlators are both expensive and not suited to the processing of data containing periodicities of low frequency. This paper describes a correlator that can be readily assembled from commercially available subassemblies. It is capable of computing the auto- or cross-correlation functions of data having low frequency components. The storage of data and provisions for the introduction of a variable delay required in computation is instrumented by a magnetic tape recorder. This work was sponsored by an Air Force contract to study radar terrain-return signals.

**47. OPTIMUM TECHNIQUES FOR DETECTING PULSE SIGNALS IN NOISE**

D. L. DRUKEY

(Hughes Aircraft Company, Culver City, Calif.)

The problem treated is that of processing  $N$  samples of signal plus noise or noise alone so as to obtain the maximum probability of correctly identifying a pulse-type signal as present, consistent with a given probability of calling noise a signal. The signal and noise are treated statistically, and the effect of signal amplitude fluctuations is taken into account. In addition to specifying optimum processing methods, the false alarm probabilities and probabilities of detecting a signal have been calculated for these optimum systems and for several different signal characteristics.

**Microwaves I—Waveguides A**

Chairman, G. C. SOUTHWORTH  
(Bell Telephone Laboratories, Inc., Holmdel, N. J.)

**48. MICROWAVE WIRING**

D. D. GRIEG AND H. ENGELMANN

(Federal Telecommunication Laboratories, Nutley, N. J.)

A novel approach to microwave transmission results from replacing the familiar waveguide or coaxial line with a signal wire or strip supported above a ground plane.

This structure is approximately equivalent to a parallel-wire system, but by virtue of an "image" of the wire in the ground plane, adequate symmetry is achieved without dimensional criticalness. The spread of the field about the conductor is small and the losses approximate those that characterize a coaxial structure.

Printed-circuit techniques are particularly applicable to these microwave transmission systems and make possible the construction of compact, rugged, and relatively inexpensive microwave components.

**49. SIMPLIFIED THEORY OF TEM PROPAGATION ALONG CONDUCTOR-GROUND-PLANE TRANSMISSION SYSTEMS**

F. ASSADOURIAN AND E. RIMAI

(Federal Telecommunication Laboratories, Nutley, N. J.)

Characteristic impedance, power distribution, and transmission losses for transverse electromagnetic (TEM) propagation in infinite transmission systems comprising a conductor above ground were treated by an electrostatic approach using conformal mapping in the image plane.

The cases of wire and zero-thickness strips of varying height-to-width ratios above infinite ground are discussed. An assumed small thickness permits calculation of strip losses without greatly disturbing the fields except at the strip edges. The effect of finite ground width is also treated. Finally, the effect of a slot in the ground plane is examined for both wire and strip above ground.

**50. MICROWAVE COMPONENTS FOR CONDUCTOR-GROUND-PLANE TRANSMISSION SYSTEMS**

J. A. KOSTRIZA

(Federal Telecommunication Laboratories, Nutley, N. J.)

A new type of microwave transmission line has been developed that is adaptable to fabrication of wide-band microwave components of reasonable cost. It employs an open waveguide system consisting of two parallel conductors, one acting as a line and the other as a ground conductor.

Detailed descriptions are given of experimental techniques and results in the construction of components for operation in the 5,000-megacycle region. Among these components are transducers to coaxial lines, loads, and pads; crystal mounts; "rat races"; directional couplers; and shunt T-junctions. Data are included for wire-above-ground, "printed," and "sandwich" lines.

**51. METHOD FOR OPEN WAVEGUIDE STANDING-WAVE MEASUREMENTS**

S. W. ATTWOOD AND G. GOUBAU

(Signal Corps Engineering Laboratories, Fort Monmouth, N. J.)

In order to measure standing-wave ratios at microwave frequencies on open waveguides, a new indirect method had to be employed because there were no satisfactory standing-wave detectors available for these types of guides. The method employs a thin dielectric disk which intercepts the field and is moved along the guide. The disk causes a change of input impedance which depends on the location of the disk. The ratio of maximum to minimum impedance change is proportional to the square of the standing-wave ratio. Two methods for determining this ratio will be discussed.

**52. NEW GUIDED WAVE TECHNIQUES FOR THE MILLIMETER WAVELENGTH RANGE**

A. G. Fox

(Bell Telephone Laboratories, Inc., Holmdel, N. J.)

The results of preliminary experiments with new guided wave techniques at 48 kmc make it appear that such will be very useful in the millimeter wavelength range. These techniques provide the only practical means yet known for obtaining flexible transmission links in this range. They afford an easy way of obtaining directional couplers having practically any desired value of coupling loss.

**SYMPOSIUM****Television Broadcasting; Audio and Video Systems**

(Organized by Professional Group on Broadcast Transmission Systems)

Moderator, W. B. LODGE

(Columbia Broadcasting System, New York, N. Y.)

**53. FIXED AND MOBILE TV LIGHTING**

EMERO FIORENTINO

(WJZ-TV, New York, N. Y.)

Television lighting of today has emerged from the laboratory stage where it was merely a physical device used to activate the electro-sensitive systems. It is now an excellent example of the marriage between the artistic and highly technical elements of a production, a marriage so necessary in the television industry.

Because of the rapid advancement that television lighting has been going through, many of its old principles are still adhered to religiously by many people. These people undoubtedly neither have had the time nor the money nor, most important of all, information concerning new developments which has not been made available and meaningful to them. By the same token, those who are employing better lighting techniques have had their hands full with that job and consequently there has been little time for elaborate, large-scale discussion of the lighting problems and techniques of today.

Through this paper, there will be provided information concerning these lighting techniques; the adaptation of motion picture lighting and the many facets peculiar to lighting in TV.

#### 54. THE TRANSIENT RESPONSE OF TV TRANSMITTER-RECEIVER SYSTEMS

J. RUSTON

(Allen B. DuMont Laboratories, Inc., Passaic, N. J.)

The results of an experimental investigation of the transient response of TV transmitters are presented and substantiated as far as practicable by partial theoretical analyses. In a vestigial sideband system, the transmitter response must be considered in relation to the over-all response of the transmitter and receiver. The effect of the transmitter characteristics on the system response is considered for various types of receiver characteristics. Methods for correcting possible deficiencies in the transmitter are suggested. The possibility of including correction in the transmitter for common deficiencies in the receiver is discussed, and doubt is expressed regarding its desirability. A method is suggested whereby a change of transmitter and receiver standards would largely eliminate the transient distortion inherent with the present standards.

#### 55. MEASUREMENT OF TV FIELD INTENSITIES BY HELICOPTER

J. G. PRESTON

(American Broadcasting Company, New York, N. Y.)

Recent use of a helicopter to measure the horizontal field intensity pattern radiated by a typical vhf TV broadcast antenna installation is reported. Field intensity recordings of unusual quality were obtained through measurement on a circular flight course at an appropriate radius from the antenna. The measurements disclosed pattern non-circularity in excess of the tolerance permitted by the antenna specifications. Through the use of appropriate assumptions, it is found possible to verify mathematically the measured pattern and to determine antenna phasing changes necessary to bring the pattern within the original specifications. Subsequent helicopter measurements of the rephased antenna confirmed performance within specifications.

#### 56. HIGH POWER UHF KLYSTRON FOR TV SERVICE

J. J. WOERNER

(Eitel McCullough, San Bruno, Calif.)

Within the past few years it has become recognized that the cascade klystron amplifier will satisfy the specific requirements of television transmission in the ultrahigh frequency range.

The subject paper will discuss the factors involved in adapting this type of tube to the more general requirements of commercial television broadcast service. A developmental 5-kilowatt klystron designed particularly for this use will be described in detail. Features of this tube are externally tuned cavities to extend the operating range of frequency, and magnetic focussing of a type

to allow greater access to the tuning and loading arrangements.

Slides of photographs and drawings of the tube and circuit details will be shown.

#### 57. AN ULTRA-HIGH-FREQUENCY TELEVISION TRANSMITTER

E. G. MCCALL AND T. P. TISSOT

(Radio Corporation of America, Camden, N. J.)

This paper describes a TV transmitter including a 1-kw visual transmitter and a 0.5-kw aural transmitter for operation in the uhf TV band, channels 14 to 83.

A description is given of the power output stage of both visual and aural transmitter which utilizes a single high-gain air-cooled tetrode in a coaxial cavity circuit. The method of video modulation is discussed along with the phase shift FM direct crystal-controlled modulator used in the aural transmitter.

A discussion of the frequency stability requirements at uhf is given to summarize the conditions necessary for satisfactory operation of inter-carrier-sound type receivers.

### Instrumentation II—Electronic Measurements A

Chairman, E. P. FELCH

(Bell Telephone Laboratories, Inc., New York, N. Y.)

#### 58. MEASUREMENT OF IMPEDANCE AND ADMITTANCE

B. SALZBERG AND J. W. MARINI

(Naval Research Laboratory, Washington 25, D. C.)

A method is described for direct, rapid, and simultaneous measurement of the real and imaginary components of self or transfer impedance or admittance. The method employs a mixer whose signal and oscillator voltages are derived from the voltage across and current through the unknown, respectively. When the unknown is supplied by a sinusoidal constant current source, the mixer dc output is linearly related to the resistance. If the oscillator voltage phase is shifted 90° the mixer dc output is linearly related to the reactance. Apparatus using this method and operating from 50 kc to 5 mc has been built. With appropriate modifications of detail the method appears to be applicable even to microwaves.

#### 59. ACCURATE RF MICROVOLTS

M. C. SELBY

(National Bureau of Standards, Washington, D. C.)

The questionable accuracy of rf microvolts has been of great concern to the radio fields for many years. There is an urgent need for a simple, yet reliable, source of microvolts for measurements in general and for radio receiver sensitivity determinations in particular. Extremely simple devices, which seem to satisfy that need most adequately, were recently developed. These devices provide constant voltage sources of accurate microvolts for a range of 1 to 10<sup>6</sup> and wider at all frequencies to 300 mc and higher. They are adaptable for balanced and

unbalanced sources. Their electrical constants are simply determined by using known dc voltages and currents. Basic principles, design features and applications are discussed.

#### 60. AUTOMATIC SWITCHING APPLIED TO INTERELECTRODE CAPACITANCE MEASUREMENTS

R. E. GRAHAM

(Sylvania Electric Products, Inc., Kew Gardens, N. Y.)

A new equipment is described which greatly reduces the time and effort required to measure electron-tube interelectrode capacitances. The switching required for a series of measurements is performed by shielded relays which are actuated by punched cards and connected so that the resultant stray capacitance across the measurement terminals is held to a negligible amount. Design principles, description of circuits, and physical layout are given.

#### 61. MEASUREMENTS OF MILLIMETER RADIATION WITH THE PNEUMATIC HEAT DETECTOR

HANS THEISSING, H. J. MERRILL, AND J. M. MCCUE

(Signal Corps Engineering Laboratories, Fort Monmouth, N. J.)

Theoretical considerations indicate that a very thin layer of certain metals absorbs electromagnetic radiation throughout a wide range of the spectrum independently of wavelength. The absorption of such layers used as the absorbing area of a Golay pneumatic heat detector is evaluated to indicate the "grayness" of the detector. The calibrated detector is used in an optical type spectroscope to evaluate the average power emitted at the fundamental and higher harmonics of a 1.25-cm magnetron source as a function of the frequency. The signal equivalent to noise on the 12 mm diameter detector is of the order of 10<sup>-8</sup> watts.

#### 62. AUTOMATIC SMITH-CHART IMPEDANCE PLOTTER

K. S. PACKARD

(Airborne Instruments Laboratory, Inc., Mineola, N. Y.)

This system plots the impedance of a component by measuring its reflection coefficient as a termination on a 50-ohm line. A directional coupler is used to sample the direct and reflected waves on this line. By means of an electronic circuit  $K \cos \theta$  and  $K \sin \theta$ , where  $K$  is the amplitude and  $\theta$  the phase angle of the reflection coefficient, are obtained and applied to the deflection plates of a cathode-ray tube. Thus,  $K$  is plotted on a polar diagram and a Smith Chart overlay gives the impedance of the component. Two continuously sweeping oscillators, one for the 100 to 200 mc band, or one for the 200 to 400 mc band, are used so impedance is plotted over these frequency ranges.

### Television II—Color

Chairman, E. W. ENGSTROM

(Radio Corporation of America, Princeton, N. J.)

### 63. REQUISITE COLOR BANDWIDTH FOR SIMULTANEOUS COLOR-TELEVISION SYSTEMS

KNOX MCILWAIN

(Hazeltine Electronics Corporation, Little Neck, N. Y.)

It has been known for many years that the acuity of the human eye for color differences is less than for changes in brightness. It has been shown that this fact can be used to reduce the bandwidth required for simultaneous color television systems. The experiments reported here relate to psychophysical measurements made by both skilled and lay observers to determine just how far this reduction can be carried without objectionable deterioration of the reproduction. It is shown that under the conditions tested approximately one megacycle is sufficient for most color reproduction, provided four megacycles is available for brightness detail.

### 64. COLORIMETRIC ELECTRONICS

F. J. BINGLEY

(Philco Corporation, Philadelphia, Pa.)

The paper considers the relations between electrical circuits and colorimetric quantities in a color-television system. These relations are described with particular reference to a compatible color-television system of the type employing a modulating signal made up of a main monochrome component plus a color carrier. The various types of monochrome components and their colorimetric makeup are discussed. The characteristics of the color carrier and its representation by various vector systems is discussed in detail. The interrelations between these vector systems and the colorimetric quantities which they represent are demonstrated. Graphical methods are used to illustrate the analytical processes used.

### 65. THE GENERATION OF COMPATIBLE COLOR SIGNALS FOR RESEARCH AND FIELD TESTING

JOSEPH FISHER

(Philco Corporation, Philadelphia, Pa.)

This paper will describe the equipment currently being used in the research laboratories of the Philco Corporation for the generation of compatible color signals. The centralized equipment consists of a number of units such as a crystal controlled timing unit, color flying-spot scanner, burst pedestal generator and combiner. Distribution amplifiers are incorporated to feed the composite color signal to various laboratories, and microwave equipment is provided to relay the color signal to television station WPTZ for experimental broadcasts. The routing of the signal will be illustrated with block diagrams and some of the circuits used will be discussed.

### 66. A UNIVERSAL SCANNER FOR COLOR TELEVISION

G. R. TINGLEY, R. D. THOMPSON,  
AND J. H. HAINES

(Allen B. DuMont Laboratories, Inc., Passaic, N. J.)

This paper describes a flying-spot scanner for 35 mm transparencies providing three simultaneous gamma-corrected signals for any proposed color-television system.

The optical system employs a grey-faced cathode-ray tube operating at 30 kv, high definition scanning yoke, focus modulation,  $f/1.5$  objective lens, high efficiency dichroic mirror beamsplit, and three phototubes. Pictures produced have high detail contrast and signal-to-noise ratio. Horizontal resolution approximates 600 lines for compatible color and 500 lines for FCC color. Rates corresponding to either of these or to intermediate values may be switch selected. A field-sequential composite color signal at the selected rate is also produced by a keyer.

### 67. VESTIGIAL SIDEBAND TRANSMISSION OF THE COLOR SUBCARRIER IN NTSC COLOR TELEVISION

W. F. BAILEY

(Hazeltine Electronics Corporation, Little Neck, N. Y.)

In NTSC color television, the picture is encoded as a luminance signal and two additional signals representative of the color.

A color subcarrier is resolved into two synchronous components differing in phase by  $90^\circ$ , and each component is amplitude modulated by a color signal. For compatibility, the color subcarrier is near the high edge of the video band. Vestigial sideband transmission results in undesired color cross talk because of the quadrature distortion produced.

Reversal of the sequence of the color subcarrier components (color phase alternation) at field rate reverses the quadrature distortion on adjacent lines in the picture, resulting in essentially complete visual cancellation of the distortion.

## Circuits II and Information Theory III

Chairman, W. R. BENNETT

(Bell Telephone Laboratories, Inc., Murray Hill, N. J.)

### 68. NETWORKS FOR DETERMINATION OF POWER SPECTRA MOMENTS

S. H. CHANG AND W. H. LOB

(Northeastern University, Boston, Mass.)

In speech analysis studies, it is often desirable to compute the first few moments of short-time power spectra. The advantages and limits of the moment method will be explored first. Then three possible schemes of automatic computation by analogue means will be discussed. One of the schemes, employing a square-law device and filters of various rising characteristics, i.e., 10, 20, 30, etc., db/decade has been tested and will be described in more detail. Possible applications for other time series, and for the computation of the moments of distributions other than power spectra, will also be mentioned.

### 69. NONLINEAR FILTER DESIGN ON MAXIMUM LIKELIHOOD BASIS

T. G. SLATTERY

(Melpar, Inc., Alexandria, Va.)

This paper presents the theory of designing nonlinear filters using the statistical technique of the "maximum likelihood estimate." The limitations of linear filters in

separating signal from noise are reviewed and the advantages of nonlinear techniques are stated. The fact that filtering can be accomplished by estimating constants is stressed, and the advantages of this method are stated. The theory of the maximum likelihood estimate is then developed and its relationship to the Wiener type of best linear filter and the Singleton type of best nonlinear filter is described.

The example of the method is that of separating a sine wave of unknown amplitude and frequency from Gaussian noise.

### 70. OPTIMUM LINEAR SHAPING AND FILTERING NETWORKS

R. S. BERKOWITZ

(University of Pennsylvania, Philadelphia, Pa.)

Given a linear communication system consisting of a transmitter, channel, and receiver, we consider the problem of jointly optimizing the transmitter and receiver transfer characteristics. Signal power spectrum, noise, input power spectrum, power output of transmitter, and distortion of signal at transmitter are considered as being specified. The general criterion of optimization used is that the equivocation due to the noise be at a minimum. Results obtained consist of expressions for optimum transmitter and receiver characteristics in terms of the specified quantities when equivocation is monotonically related to either of two simple measures of the noise component of the receiver output.

### 71. A GENERALIZED THEORY OF FILTERING AND MULTIPLEXING

L. A. ZADEH

(Columbia University, New York, N. Y.)

AND

K. S. MILLER

(New York University, New York, N. Y.)

A theory of filtering and multiplexing based on the class properties of signals is formulated. An ideal filter is defined as one which can extract a signal belonging to a specified class from the sum of two or more signals belonging to some other specified classes. A study is made of the conditions under which two or more multiplexed signals can be separated by means of linear (variable) and nonlinear filters. These conditions are formulated in geometrical terms via the function space representation of signals and, also, in analytical terms by using the concept of  $\lambda$  domain.

### 72. FILTER TRANSFER FUNCTION SYNTHESIS

G. L. MATTHAEI

(University of California, Berkeley, Calif.)

Techniques based on the electrostatic potential analogy provide a means for synthesizing filter transfer functions to meet a variety of restrictions which may be imposed by circuit considerations. To illustrate, an example is presented of the synthesis of a filter function to be realized in an LC network, and then synthesis technique for obtaining an analogous function which meets the requirements for realization in an RC network is shown. A comparison is readily made between "efficiencies" of LC and RC realizable filter functions.

### 73. FILTERS OF MAXIMUM BANDWIDTH-IMPEDANCE RATIO PRODUCT

T. J. O'DONNELL

(Gulf Research and Development Company, Pittsburgh, Pa.)

AND

E. M. WILLIAMS

(Carnegie Institute of Technology, Pittsburgh, Pa.)

This paper is concerned with simplified methods for solving the problem of wide-band impedance transforming network synthesis in which the product of the bandwidth and impedance ratio is maximized. Conditions are developed for maximum impedance bandwidth transformations in cascades of similar transformable band-pass filter sections for two cases of special interest. One case, when applied to a standard "three-element" section is shown to lead to a network which is the lumped circuit analog of the experimental transmission line. Some experimental illustrations are given, in particular, a four-to-one ratio impedance transformer fleet from 54 to 88 mc is described.

### 74. A BAND-PASS FILTER USING SIMULATED TRANSMISSION-LINE ELEMENTS

A. D. FROST AND C. R. MINGINS  
(Tufts College, Medford, Mass.)

The use of mutually coupled coaxial transmission lines as a band-pass filter operating at frequencies of 1,000 mc and above has been described by Karakash and Mode. By utilizing various forms of synthetic transmission-line structures, the principles involved have been successfully applied to the design of filters operating in the frequency range from 2 to 8 mc. A number of these are shown together with their transmission characteristics. An important feature of this approach to the filter problem is the electrical and mechanical simplicity of the units involved.

## Medical Electronics

*Chairman*, BRITTON CHANCE

(University of Pennsylvania, Philadelphia, Pa.)

### 75. NEW ELECTRONIC TECHNIQUES FOR SPECTROPHOTOMETRY

C. C. YANG

(University of Pennsylvania, Philadelphia, Pa.)

In the course of designing a simple and compact recording spectrophotometer in the visible and ultraviolet region, new circuits have been developed for direct reading of the optical density of a solution with respect to a solvent sensitivity, accurately, and rapidly. A time sharing scheme using optical switching and a feedback circuit for ratio measurement are used to obtain the per cent absorption of the sample solution. Two analogue computing circuits are described to convert the absorption into optical density electronically. Particular emphasis is placed on the measurement of small optical density changes, and a reproducibility in optical density of about  $2 \times 10^{-4}$  is obtained.

### 76. APPLICATION OF MICROWAVES IN PHYSICAL MEDICINE

J. F. HERRICK

(Mayo Foundation, Rochester, Minn.)

A study of the effects of microwaves on certain living tissues of experimental animals prior to the acceptance of microwaves for medical diathermy will be presented.

The measurement of dielectric constant and dissipation factor of various freshly excised tissues were necessary for understanding the experimentally observed temperature distribution produced in these tissues by microwave diathermy. Results of measurements at three frequencies, i.e., 1,000, 3,000 and 8,600 megacycles will be given.

The design of a "transformer" for increasing the transfer of microwave power into tissues will be described as an example of the utility of dielectric data.

### 77. DESIGN PROBLEMS IN THE ABSOLUTE OXIMETER

R. H. TAPLIN

(Canadian Marconi Company, Montreal, Canada)

The percentage measurement in vivo of  $O_2$  in the hemoglobin of humans is carried out photometrically but precise results have been difficult to obtain. The work described here results from an investigation into the causes of error mainly from an instrument design point of view. It is confined to the electronic type of oximeter of Goldie and later developed by Paul which gives the greatest flexibility. Large photometric errors are overcome by the new earpiece described, and the required design parameters of stability in earpieces, electronic amplifiers, discriminators, and light modulators are discussed. It seems possible to achieve a long term instrumental drift better than  $\pm 3$  per cent and a short term of  $\pm 1$  per cent for several hours.

### 78. TELEVISION MICROSCOPY IN THE ULTRAVIOLET

V. K. ZWORYKIN, L. E. FLORY, AND R. E. SHRADER

(Radio Corporation of America, Princeton, N. J.)

The differential absorption of tissues and micro-organisms in the ultraviolet is an important aid in medical research and diagnosis. The television microscope, provided with reflective optics and an ultraviolet sensitive vidicon translates ultraviolet intensities directly into brightness differences and circumvents the time lag inherent in photographic methods. With the aid of a pulsed ultraviolet source, a suitable wavelength selecting system and a color receiver partial images in three different primary colors, corresponding to three selected ultraviolet wavelengths, may be presented to the eye in rapid succession. This permits an immediate recognition of localized differential absorptions by color differences. Problems arising in the construction of the above device are discussed.

### 79. RECORDING MULTI-AXIAL PROJECTION OF VECTORCARDIOGRAMS: THE AXOSTAT

B. P. MCKAY, W. E. ROMANS, D. A. BRODY, AND R. C. LITTLE

(University of Tennessee, Memphis, Tenn.)

Present electrocardiographic instrumentation necessitates recording from many different electrodes to determine transition points which delineate the indices of ventricular gradient. With the "Axostat" these transition points are located by recording from only four electrodes. A patient is connected through appropriate switches to a wye (Wilson central terminal) and inverted delta resistance network. A sliding contact on the delta network allows voltages to be taken through 360 degrees with respect to the center of the wye. The relation of these voltages to the normal electrocardiographic potentials is a calculable function for the angular position of the contact. This has shown a need for calibrated preamplification in order that recordings may be taken at normal electrocardiograph amplitudes. Circuitry is described for the above networks and preamplifier. For clinical application simplified resistive networks are shown which do not require preamplification and can be used directly with many standard electrocardiographs.

### 80. CONTINUOUS INTEGRATING COUNTING-RATE SYSTEM FOR RADIOACTIVITY

MONES BERMAN AND SALVATORE VACIRCA  
(Sloan-Kettering Institute, New York, N. Y.)

An instrument is described that continuously computes the counting rate of a source by integrating the total number of counts and giving an accuracy at any time characteristic to the number of counts collected. The count integration is obtained by converting the counts into a voltage proportional to its number. This voltage is continuously balanced against another voltage which varies linearly with time. The latter voltage is obtained by driving a potentiometer with a synchronous motor. For balance between the two voltages to be maintained, the total voltage across the potentiometer must be proportional to the integrated counting rate and is, hence, a measure of it. Adjustment of this voltage for balance conditions is made either manually or automatically.

## Microwaves II—Waveguides B

*Chairman*, A. G. KANDOIAN

(Federal Telecommunication Laboratories, Inc., Nutley, N. J.)

### 81. NONUNIFORM TRANSMISSION LINES

J. G. GURLEY

(Hughes Aircraft Company, Culver City, Calif.)

Transmission lines with tapered mechanical dimensions or electrical properties are analyzed in terms of interactions between modes. A rigorous solution of the electromagnetic field problem is obtained by considering all modes; when only one mode has appreciable amplitude then the results are consistent with quasi-static transmission line concepts.

A by-product of this investigation is an expression for characteristic impedance which is valid for waveguides as well as for two-conductor lines. Successful measurements were made on a rectangular waveguide with a vertical dielectric web of tapered thickness.

## 82. THE OPTIMUM PISTON POSITION FOR COAXIAL-TO-WAVEGUIDE TRANSDUCERS

W. W. MUMFORD

(Bell Telephone Laboratories, Inc., Holmdel, N. J.)

A coaxial line can be matched to a waveguide by means of a probe antenna located ahead of a short circuiting plunger. An impedance match can be achieved by varying any two of the following three dimensions; (a) the probe length; (b) the piston position; (c) the off-center position of the probe.

This paper points out that there is, theoretically, an optimum piston position for greatest bandwidth, and presents some evidence corroborating this theory. Bandwidths of  $\pm 10$  per cent to the 1 db SWR have been realized by fixing the piston position at its optimum and varying (a) and (c) above to obtain a match.

## 83. BROAD-BAND RIDGED AND FLATGUIDE COMPONENTS 10-40 KMC

SAMUEL HOPFER

(Polytechnic Research and Development Company, Inc., Brooklyn, N. Y.)

Two basic transmission systems have been selected for the construction of broad-band components in the range from 10-40 kmc/sec, namely, the ridged guide and the flat guide. The former is a single mode system and useful for broadband receiver work. The components to be discussed are: Tuner, Crystal Mount, Attenuator, and Tapers. The flat guide system useful for transmission work is capable of supporting higher modes. The type of discontinuities employed in the construction of components do not generate higher modes. The flat guide components to be discussed are: Tuner, Crystal Mount. The equivalent circuit of a third mode generator such as the inductive window is given.

## 84. STEP-TWIST WAVEGUIDE COMPONENTS

HENRY SCHWIEBERI AND H. A. WHEELER

(Wheeler Laboratories, Great Neck, N. Y.)

The step twist is a sequence of short sections of rectangular waveguide twisted about their common axis, having graduated dimensions and angles determined by techniques newly developed for this purpose. The fixed twist supplants the much longer twisted waveguide with advantages in wideband matching in shorter space by greater freedom of dimensioning and greater reproducibility. A 90° fixed twist, handling the rated 40 per cent frequency bandwidth of the waveguide within 0.3 db SWR is made in a length only  $3/2$  the guide width. The step twist has been adapted to rotary designs in lengths proportional to the required refinement of wideband matching.

## 85. WAVEGUIDE MATCHING TECHNIQUE

W. C. JAKES, JR.

(Bell Telephone Laboratories, Inc., Holmdel, N. J.)

This paper presents the results of a theoretical and experimental study of a new waveguide matching technique. The main advantage of the method described is that the technique may be applied at any distance away from the discontinuity causing the original mismatch and a broad-band match may still be obtained.

Design curves are included which give the required parameters for the technique and the power loss for a given initial mismatch and desired VSWR reduction. Experimental confirmation of the theory is also presented.

## SYMPOSIUM

### TV Station Construction and Theater Conversion

(Organized by Professional Group on Broadcast Transmission Systems)

Moderator, R. F. GUY

(National Broadcasting Company, New York, N. Y.)

## 86. THE NEW WOR-TV STUDIO AND TRANSMITTER BUILDING AT 60TH STREET AND COLUMBUS AVE., NEW YORK CITY

J. R. POPPELE

(WOR-TV, New York, N. Y.)

## 87. NEW BUILDING AND TECHNICAL FACILITIES AT WCAU-TV, PHILADELPHIA

J. G. LEITCH

(WCAU, Philadelphia, Pa.)

## 88. THE WFAA-TV PLANT, DALLAS, TEXAS

C. L. DODD

(Dallas News-The Dallas Journal, Dallas, Tex.)

The foregoing trio of papers, 86, 87, and 88 will offer a detailed report on the physical, mechanical, and electrical problems involved in the preparation, construction, installation, and operation of new TV broadcasting facilities.

## 89. THEATER-TV CONVERSIONS (a). NBC PROGRAM

A. A. WALSH

(National Broadcasting Company, New York, N. Y.)

## (b). CBS PROGRAM

A. B. CHAMBERLAIN

(Columbia Broadcasting System, New York, N. Y.)

## (c). ABC PROGRAM

J. M. MIDDLEBROOKS

(American Broadcasting Company, New York, N. Y.)

In (a), (b), and (c) above, there will be offered a comprehensive survey of all of the

interesting aspects relating to the physical, mechanical, electrical, audio, and video equipment requirements in typical converted legitimate theatres or motion picture theatres in New York City.

Topics to be covered will include lease or purchase negotiations, typical conversion schedules, major modifications usually necessary, scenery and prop handling, typical floor plans (before and after conversion), and layout arrangements (stage and audience areas, control room, equipment room, studio-mc interconnections, etc.)

## SYMPOSIUM

### Present Status of NTSC Color-Television Standards

Chairman, A. G. JENSEN

(Bell Telephone Laboratories, Inc., Murray Hill, N. J.)

90. A panel of leading color-television engineers will discuss the most recent work of NTSC panels towards the preparation of standards for the NTSC color-television system. The discussion will include any available results of the field tests currently being conducted under such standards.

### Instrumentation III—Electronic Measurements B

Chairman, R. R. BATCHER

(Radio Television Manufacturers Association, New York, N. Y.)

## 91. A RASTER SWEEP OSCILLOGRAPH FOR PRECISION TIME MEASUREMENTS

H. B. STEINHAUSER

(Allen B. DuMont Laboratories, Inc., Clifton, N. J.)

The equipment described provides a means for analyzing the time relationships between electrical pulses. A raster type presentation is used in order to combine the advantage of a fast sweep for accurate time determination with a long time base for extended range of measurements. Incoming video signals produce vertical deflection, while the raster sweep is triggered from an external pulse. The display is photographed and the oscillogram enlarged to obtain reading accuracy commensurate with measurement accuracy. The complete unit is mounted in a dust-tight cabinet with pressure ventilation. Slide mounts allow each individual chassis to be pulled out, tilted upward 90°, and locked in position for servicing.

## 92. PRECISION AUTOMATIC TIME MEASUREMENT EQUIPMENT

D. W. BURBECK AND W. E. FRADY

(Hughes Aircraft Company, Culver City, Calif.)

Equipment using a new method for automatically measuring time differences to an average accuracy of 0.008 microsecond over the range of 25 to 600 microseconds is de-

scribed. The principle of operation involves two steps—first, the number of 2.0 megacycle pulses occurring in the interval to be measured are counted, then the interpolation between the 2 mc pulses is carried out by a pulse counting vernier technique which gives an over-all accuracy of 0.008 microsecond for the measurement. The vernier interpolation provides high precision without exceeding a 2 mc counting rate.

The final result of the measurement appears as a number in a binary counter. The range of the system may be readily extended by increasing the frequency stability of the 2 mc frequency source.

### 93. A ROTATING-BEAM CEILOMETER SYSTEM

R. H. GUENTHER AND L. W. FOSKETT  
(U. S. Weather Bureau,  
Washington 25, D. C.)

This ceilometer system indicates cloud heights every 24 seconds. It works by triangulation and comprises a detector, projector, and indicator. The detector is a lead-sulphide cell with parabolic reflector. The projector includes a modulated light source with another reflector. The detector "sees the zenith" and the projector, by suitable rotation, scans the detector field of view. The indicator is a 5-inch cathode-ray tube with a peripheral height scale. The indicator spot moves 360 degrees while the projector scans the detector field of view. Detected signals deflect the spot radially toward the scale, thus indicating cloud height. Measurements up to 2,000 feet are made consistently, both day and night.

### 94. A POLAR-COORDINATE CATHODE-RAY OSCILLOGRAPH FOR USE WITH THE ROTATING-BEAM CEILOMETER

M. T. NADIR AND M. B. KLINE  
(Allen B. DuMont Laboratories, Inc.,  
Clifton, N. J.)

A polar-coordinate cathode-ray oscillograph designed specifically for cloud-height measurements in the U. S. Weather Bureau's new rotating-beam ceilometer system is described. An automatically synchronized circular baseline is produced on a Type 5CP7-A cathode-ray tube, with a selected 36° sector scanned by the searchlight spread out over a 360° circle. The signals picked up by the photocell detector of the ceilometer system produce radial deflection simultaneously with automatically produced altitude markers. Using a 500 foot baseline, a range of altitude from zero to beyond 14,000 feet may be indicated. Accuracies of a few feet in altitude are attained on the 400 foot range.

A number of the novel circuits used in the oscillograph are described. The unique mechanical and optical system utilizes unitized design to facilitate changes of baseline for different installations and maintenance in the field.

Standard oscillograph-record cameras may be used for making photographic records.

### 95. AN ELECTRONIC FRINGE INTERPOLATOR FOR AN OPTICAL INTERFEROMETER

R. D. HUNTOON  
(National Bureau of Standards,  
Corona, Calif.)

In the interferometer method, precision length measurements require careful interpolation between fringes. This electronic interpolator generates an FM wave by vibrating a plate with an amplitude of about  $\lambda/4$ . The exact amplitude is determined by analyzing the wave, and the result is displayed on a cro indicator.

Interpolation to about 1/100 fringe has been accomplished.

## Television III— General B

Chairman, I. J. KAAR  
(General Electric Company,  
Syracuse, N. Y.)

### 96. THE PROBLEM OF INTERLACE IN TELEVISION RECEIVERS

J. DE LEON  
(Allen B. DuMont Laboratories, Inc.,  
East Paterson, N. J.)

With the continuing trend toward larger picture tubes in television receivers, more attention is necessarily directed toward improvement of interlace.

Various types of noninterlace are examined, with special attention to the form evidenced as stable pairing. This form is generally attributed to interfering voltage coupled to the vertical oscillator from horizontal sweep circuits. It is shown that similar misinformation may be obtained from the incoming sync signal.

Means of reduction of interfering pickup are discussed, together with certain methods of reducing susceptibility of vertical oscillator circuits to interference. Tools and techniques applicable to experimental investigations are described.

### 97. A METHOD OF EVALUATING THE PERFORMANCE OF A TELEVISION PICTURE TUBE AND ITS ASSOCIATED COMPONENTS

JULIUS GREEN  
(Philco Corporation, Philadelphia, Pa.)

The paper describes a method for evaluating the distribution of light intensity across a scanning line of a picture tube, the equipment used, and the results obtained. The method employed involves illuminating only a single line of a standard television pattern, and imaging it through a fine optical slit onto a photocell.

There is produced on a cathode-ray oscilloscope a trace the ordinates of which are proportional to the distribution of luminous intensity on the picture tube.

An adaptation of this method to measure the relation between contrast and resolution is described.

### 98. CHARACTERISTICS AND PERFORMANCE OF TELEVISION CLAMPING CIRCUITS

A. J. BARACKET  
(Federal Telecommunication Laboratories,  
Nutley, N. J.)

Clamping circuits are used to insert direct-current information into studio camera chains, picture monitors, and receivers. They permit the use of coupling circuits

having relatively poor low-frequency response, which tend to suppress the effects of hum and microphonics. Direct-current error, recovery time, synchronization loading, and noise bursts are considered under extreme noise and signal variations. Immunity to noise and recovery time are functions of the clamp coupling capacitance and the duration of the clamping pulses. It is shown that compromises may often be employed to satisfy the requirements of both immunity to noise and good recovery time.

### 99. COLOR-TELEVISION SYNCHRONIZING-GENERATOR CIRCUITS

I. KRAUSE, A. J. BARACKET, AND H. DELL  
(Federal Telecommunication Laboratories,  
Nutley, N. J.)

Binary frequency dividers with feedback loops and accurate gating and keying circuits are employed in generating timing signals and in shaping pulses for field-sequential color television. Generating and positioning of the color pulse during the red field are described. The 48-cycle frame pulses are locked to the 60-cycle power-line frequency by separate circuits. Crystal control is also provided at ten times the equalizing pulse rate. 583-kilocycle marker signals, 0.6-microsecond wide, are generated at a 2.16-kilocycle burst rate and may be mixed with blanking pulses for checking sweep linearity of color monitors and receivers.

### 100. PRINTED UNIT ASSEMBLIES FOR TELEVISION

W. H. HANNAHS AND NORMAN STEIN  
(Sylvania Electric Products, Inc.,  
Bayside, N. Y.)

A one-stage module is described for TV receiver construction. Etching and silk-screening techniques are combined to produce a completely "printed" unit assembled by solder-dipping, which interconnects with other stages without wire. Design data and performance are given for a 25 mc IF. This type of construction is usable for most of the stages in present receivers and is expected to save critical materials. Resistors are fabricated to commercial tolerances.

## Circuits III

Chairman, H. A. WHEELER  
(Wheeler Laboratories, Great Neck, N. Y.)

### 101. THE EFFECTIVE BANDWIDTH OF VIDEO AMPLIFIERS

F. J. TISCHER  
(Stockholm, Sweden)

Investigation of some relations existing between transient response and transfer function on a steady-state basis of video amplifiers shows that it is possible to derive directly from the complex transfer function an "effective" bandwidth as a figure of merit for the relative utility of the amplifier for transient application. The effective bandwidth is independent of the shape of the amplitude characteristic and takes account of the phase characteristic. Important relations are investigated.

### 102. TRANSIENT RESPONSE OF CATHODE PEAKED VIDEO AMPLIFIERS

J. H. MULLIGAN, JR.

(New York University, New York, N. Y.)

AND

L. MAUTNER

(Hughes Research and Development Laboratories, Culver City, Calif.)

Consideration is given to the effect produced on the step function transient response of a video amplifier when cathode peaking is added. Conclusions are drawn concerning the effects produced on the transient response of a video amplifier of general form when this type of peaking is used. The results are obtained primarily by utilizing the theory of the dependence of step function response upon pole and zero locations in the complex frequency plane.

To illustrate the analysis presented, examples will be given showing the effect of cathode peaking on the transient response of several common video amplifier configurations.

### 103. VARIABLE BANDWIDTH-AMPLIFIER DESIGN FOR HIGH RATE OF CUTOFF AND LARGE BANDWIDTH VARIATIONS

M. DISHAL

(Federal Telecommunications Laboratories, Nutley, B. J.)

Variable-bandwidth intermediate-frequency amplifiers are often required. For large bandwidth variation and high rate of cutoff in the narrow-band condition, the usual overcoupled double-tuned circuit with variable coupling combined with a single-tuned circuit ( $n=3$ ) will not do.

Exact design data will be given for variable-bandwidth intermediate-frequency amplifiers using cascades of 1 to 4 different double-tuned circuits ( $n=1$  to 8). The design methods are based on the known desired location of the poles of the required response shape, and the information will be presented in a graphical form that is quite simple to use.

### 104. COUPLING CIRCUITS HAVING FLAT-AMPLITUDE CHARACTERISTICS

A. B. MACNEE

(University of Michigan, Ann Arbor, Mich.)

Adjustment of peaking circuits for flat amplitude response is considered, such adjustment being desirable when wide bandwidths without good transient response are required. Modified versions of the series-peaking and series-shunt-peaking circuits are analyzed. The circuit parameters necessary to give an optimum flatness of the amplitude response curve are presented for all ratios of input to output capacity. Gain-bandwidth factors of from  $\sqrt{2}$  to 2.7 are achievable with circuits adjusted in this manner. Modification of the circuits for good transient response will also be discussed.

### 105. OSCILLATOR SYSTEMS CONTROLLED BY PHASE DETECTOR REACTANCE TUBE

J. C. TELLIER AND G. W. PRESTON

(Philco Corporation, Philadelphia, Pa.)

Conditions under which a phase-detector reactance-tube controlled oscillator will synchronize with a reference signal will be analyzed and a basic equation derived. If certain relations hold among the parameters of the equation, synchronization will occur for a given value of initial frequency difference between oscillator and reference signals, for any value of initial phase difference. These relations will be presented graphically. An approximate analytic expression for this curve is used to obtain an equation which describes the lock-in performance in terms of the cutoff frequency of the RC network and the permissible static phase error after synchronization.

### 106. ESSENTIAL INSERTION LOSS

D. R. CROSBY

(Radio Corporation of America, Camden, N. J.)

The idea of essential insertion loss has both theoretical and practical advantages. Unlike the usual insertion loss, it is the property of a two-port net and so is independent of the terminations of the net.

In certain important cases at microwave frequencies, it is more easily measured with conventional test equipment than insertion loss. The theory yields useful theorems which are not true for insertion loss, and is descriptive of important filter properties concerned with microwave duplex filters.

## Propagation

Chairman. A. E. CULLUM, JR.

(Consulting Radio Engineer, Dallas, Tex.)

### 107. THE POLARIZATION OF VERTICALLY INCIDENT LONG RADIO WAVES

J. M. KELSO, H. J. NEARHOOF,

R. J. NERTNEY, AND A. H. WAYNICK

(Pennsylvania State College, State College, Pa.)

The polarization of long electromagnetic waves in the ionosphere is considered. The analytical expressions relating the  $N-\nu$  distributions of the ionosphere to the characteristic polarization are developed. The polarization of the electromagnetic wave leaving the ionosphere is treated in two ways. In Part I the wave is treated as a single magneto-ionic component. It is shown that under certain conditions the wave does behave as a single component which attains a "limiting polarization" at some  $N$  value  $N \neq 0$ . It is shown, however, that this analysis "breaks down" under certain conditions and, in fact, wave polarizations occur which are not characteristic polarizations associated with any  $N-\nu$  value.

It is shown in Part II that a model consisting of electrons  $D$  and  $E$ -regions is capable of giving polarization results which are in good agreement with experiment.

### 108. RADIO TRANSMISSION BEYOND THE HORIZON IN THE 40-4,000 MC BAND

KENNETH BULLINGTON

(Bell Telephone Laboratories, Inc., New York, N. Y.)

Reliable signals have been received at distances of several hundreds of miles at frequencies of 500 and 3,700 mc. The median signal levels are 50-90 db below the free space field but are hundreds of db (in one case 700 db) stronger than the value predicted by the classical theory based on a smooth spherical earth with a standard atmosphere. Antenna gains and beamwidths are maintained to a first approximation and no long delayed echoes have been found. The experimental results are compared with other available data.

### 109. TROPOSPHERIC PROPAGATION DATA ON FREQUENCIES BETWEEN 92 AND 1,047 MC AT DISTANCES FAR BEYOND THE HORIZON

G. R. CHAMBERS, J. H. CHISHOLM,

J. W. HERBSTREIT, AND K. A. NORTON

(National Bureau of Standards, Washington, D. C.)

Preliminary measurements have been made at distances between 50 and 400 miles of the signal power received from conventional 3 kw vhf transmitters and from a specially designed 4 kw continuous-wave crystal-controlled 1,047 mc klystron transmitter located on Cheyenne Mountain in Colorado. The distance ranges at which the measurements could be made were increased by confining the radiated energy to a narrow frequency band. Contrary to expectation from either standard atmosphere or duct theory, the measured attenuation rate (db per mile) was not constant at large distances beyond the horizon but increased markedly and continuously out to the maximum distance covered.

There was some evidence that the received signals were propagated at least in part via some scattering mechanism, but this scattering was not sufficient at a point far beyond the horizon to appreciably reduce the gain (24 db) or change the pattern expected with plane waves for a 10-foot paraboloidal antenna at 1,047 mc.

### 110. STATISTICAL FLUCTUATIONS OF RADIO FIELD STRENGTH FAR BEYOND THE HORIZON

S. O. RICE

(Bell Telephone Laboratories, Inc., New York, N. Y.)

When a sinusoidal radio wave of extremely high frequency is sent out by a transmitter, the wave received far beyond the horizon is often observed to fluctuate. Here some of the statistical properties of this fluctuation are derived on the Booker-Gordon assumption; namely that the received wave is the sum of many little waves produced when the transmitter beam strikes "scatterers" distributed in the troposphere. Expressions are obtained for the periods of the fluctuations in time, in space, and in frequency. These expressions extend closely related results obtained by Booker, Ratcliffe, and others.

# 111. SOME CONSIDERATIONS IN THE USE OF HIGHLY DIRECTIONAL ANTENNAS ON SOURCES OF COMPARABLE ANGULAR SIZE TO THE BEAMWIDTH

D. O. McCoy

(Collins Radio Company,  
Cedar Rapids, Iowa)

Particularly in the field of radio astronomy, it is necessary to receive energy from sources that subtend angles comparable to that of the beamwidth. Under this condition, both the gain and the effective beamwidth of the antenna are altered. The discussion begins with a review of some of the fundamentals involved, revealing the nature of the variations encountered with non-point sources. The results of a theoretical analysis of the problem are presented. The discussion ends with a bit of philosophy comparing radio antennas with optical systems.

## Microwaves III—Filters and Circuits

Chairman, D. D. KING

(The Johns Hopkins University,  
Baltimore, Md.)

### 112. FURTHER TRANSMISSION ANALYSIS OF HYBRID RINGS

H. T. BUDENBOM

(Bell Telephone Laboratories, Inc.,  
Whippany, N. J.)

A paper presented at the 1948 IRE National Convention gave an analysis of the hybrid ring as a re-entrant transmission line. The present paper is in many respects a summary of advances in the study of four-arm series hybrid rings since that paper. Work by L. J. Cutrona and H. Kahn is mentioned; the remainder of the work is from Bell Laboratories sources. The second section of the paper gives: (a) procedure for including the effect of conductor resistance; (b) discussion of peak conjugacy and impedance characteristics, the latter including discussion of optimum waveguide annulus width; (c) effective equivalent "T" section length; and (d) phase effects of impedance in conjugate leg. The paper concludes with discussion of a multiplying property of the four-arm series hybrid ring.

### 113. RESONANT CAVITY BAND-PASS FILTERS—PRACTICAL ADJUSTMENT TO PREDICTED PERFORMANCE

D. DeWITT, M. KLEIN, AND T. J. POTTS, JR.  
(Radio Receptor Company, Inc.,  
Brooklyn, N. Y.)

Using the procedures given here, band-pass filters, using three or four coupled resonant circuits at microwave frequencies, are simple to design and adjust. Design curves and a systematic procedure for adjusting each coupling and tuning parameter to realize the theoretical characteristics are presented. Calculations are based on lumped circuit representations of resonant cavities. The adjustment procedure involves the location of standing-wave minima on a slotted section preceding the filter with the filter termination uncoupled. Tables of instructions are presented based on the behavior of the input reactance of the equivalent lumped network at various stages of adjustment.

Cavities are assumed lossless, isochronous narrow-band approximations are made, and lumped coupling is assumed.

### 114. SYNTHESIS OF NARROW-BAND DIRECT-COUPLED FILTERS

H. J. RIBLET

(Microwave Development Laboratories,  
Inc., Waltham, Mass.)

A general synthesis procedure for the design of narrow-band direct-coupled filters is based on an approximate first-order equivalence between direct and quarter-wave coupled filters. Thus a quarter-wave coupled filter, whose bandwidth is a few per cent wider than required, serves as a prototype. The approximations underlying the general synthesis procedure for quarter-wave coupled filters, given by Lawson and Fano and applied by Mumford to the maximally flat case, are re-examined and justified. The transmission characteristics of a three- and a six-cavity filter, each of total  $Q$  of about 50, are computed exactly, with excellent agreement with the design performance.

### 115. ON HIGH-K DIELECTRIC CAVITIES

H. M. SCHLICKE

(Allen-Bradley Company,  
Milwaukee, Wis.)

This paper is concerned with resonance phenomena in cylinders in high- $K$  dielectrics. These "cavities" are extremely small in terms of the wavelength. All four combinations of radial and axial impedance being zero (metallized dielectric) or infinite (interface dielectric/air) are investigated. In contradistinction to conventional cavity theory, dealing only with metallic boundaries, quasi-degenerated TE modes are realizable for nonmetallized faces of the cylinder. The proper mode for high- $K$  disk condensers is also derived. The "cavities" are easily tunable by magnetic rods. A dielectric spiral, evolved from the quasi-degenerated  $TE_{010}$  mode, and encircling a magnetic rod constitutes a novel type of antenna.

### 116. A DUAL-CHANNEL COLINEAR ROTARY JOINT

E. O. HARTIG

(Goodyear Aircraft Corporation,  
Akron, Ohio)

This paper describes a dual-channel colinear rotary joint designed for use at X band. The input and output transitions are identical and consist of two rectangular waveguides coupling into orthogonal  $TE_{11}$  modes in circular waveguide. Between the two transitions is a 180 degree differential phase shifter which rotates at half the speed of the output junction.

The matrix theory of this rotary joint has been derived. A theoretical study has also been made to determine the effect of misalignment of the elements, variations in the differential phase shift and mismatch of the load.

A rotary joint of this type has been fabricated, tested, and shown to have greater than 35 db decoupling between channels and a very low VSWR over a 6% frequency band.

## SYMPOSIUM

# Digital Computers in Control Systems

(Organized by Professional Group on Radio Telemetry and Remote Control)

Chairman, J. W. FORRESTER

(Massachusetts Institute of Technology,  
Cambridge, Mass.)

The Symposium will deal with the application of digital computers and digital techniques to the solution of a large scale control problem in which information is available at remote points and control functions are to be performed at remote places. The four operations of coding, communicating, computing, and display will be covered.

### 117. DIGITAL COMPUTERS IN CONTROL SYSTEMS

J. W. FORRESTER

(Massachusetts Institute of Technology,  
Cambridge, Mass.)

Control and data collection systems are rapidly becoming larger in physical extent and more complex in the tasks which are assigned. For long distance transmission of multi-channel precision data, pulse-code digital modulation systems have been employed. With new advances in analog-to-digital translation devices and in high-speed digital computers, the all-digital integrated system is fast becoming a reality. The new systems need for their successful execution a keen awareness of the "systems engineering" task. Proper displays and the coupling between persons and the system become increasingly important.

### 118. CODERS

R. P. MORK

(Raytheon Manufacturing Company,  
Waltham, Mass.)

A description is given of several practical digital coding methods for use in control systems, and their advantages are assessed. Coding methods suitable for use with both electrical and mechanical input data are included. The paper discusses the problem of coding at high speeds, as required when multiplexing several data channels for transmission over a single link, with a presentation of some unusual techniques for increasing maximum coding speeds and reducing the average quantizing error.

### 119. DATA TRANSMISSION LINKS

P. PONTECORVO

(Raytheon Manufacturing Company,  
Waltham, Mass.)

Some of the general problems encountered in the transmission of information in digital form over microwave links are discussed. The solution of some of these problems in one particular application are described in more detail.

### 120. THE DIGITAL COMPUTER AS A CONTROL ELEMENT

C. R. WIESER

(Massachusetts Institute of Technology,  
Cambridge, Mass.)

When a digital computer is used to control a large-scale physical system, the computer's capability for carrying out logical as well as arithmetic operations makes it a key element in planning the entire system. Before the question of "how to compute," comes the question of "what to compute," and this must be decided, exactly and in detail, before either the system behavior or the computer requirements can be precisely defined. The desired functional behavior of the system must be broken down into a pattern of simple logical steps, which can be translated into instructions for the computer to follow.

## 121. DISPLAY ELEMENTS

B. S. BENSON

(Benson-Lehner Corporation, West Los Angeles, Calif.)

The flow of information between digital devices and human beings is discussed with reference to communication and control. A survey of available equipment and future trend is also discussed.

## Antennas I—General

Chairman, L. C. VAN ATTA

(Hughes Aircraft Company, Culver City, Calif.)

## 122. OPTIMUM PATTERNS FOR ARRAYS OF NONISOTROPIC SOURCES

GEORGE SINCLAIR

AND

F. V. CAIRNS

(National Research Council, Ottawa, Canada)

The problem of synthesizing the optimum pattern for an array of nonisotropic sources will be discussed. The mathematical conditions to be satisfied by the polynomial representing the pattern space factor will be given. It is found that trial-and-error methods yield satisfactory approximations to the optimum polynomial for arrays having up to six or eight elements. Arrays containing large numbers of elements present a more difficult problem, and various approximate methods for finding the optimum polynomial are discussed. The current distributions for a number of optimum arrays will be given.

## 123. A GEOMETRICAL METHOD OF ANALYZING THE EFFECTS OF SITE REFLECTIONS ON DIRECTION-FINDING SYSTEMS

G. A. DESCHAMPS

(Federal Telecommunication Laboratories, Nutley, N. J.)

Analysis of the response of even a simple loop direction finder to multiple rays of arbitrary polarizations and directions is difficult. Poincaré's spherical representation of ellipses permits its expression in geometrical form and general conclusions may be drawn sometimes. The effect of continuous phase change between two rays is thus interpreted.

More important is the relation between statistical optics with partially polarized light and direction finding through randomly phased site reflections, for which the notion of "partially directed" waves was introduced.

Stokes parameters from statistical optics permit analyzing such problems as finding time averages of response of one antenna.

## 124. THE RADIATED FIELDS OF PULSE-EXCITED DIPOLE ANTENNAS

C. S. ROYS

(University of Massachusetts, Amherst, Mass.)

Since there is little material available concerning the general performance of antennas with pulse excitation, the writer has developed two methods of analysis.

In the first method the input current was first expressed in Fourier integral form. This, together with the results available for antennas with cw excitation, resulted in a corresponding integral formulation for the radiated field.

The second method consisted of finding the incident and reflected current surges along the antenna. The resultant current moment was obtained next by integration. This gave an instantaneous form of the so-called "Schelkunoff radiation vector." Formulas for the oscillogram of the radiated field could then be determined by application of Maxwell's equations.

## 125. AN EXPERIMENTAL INVESTIGATION OF THE CORNER REFLECTOR ANTENNA

E. F. HARRIS

(The Antenna Research Laboratory, Inc., Columbus, Ohio)

More than 1,000 measured radiation patterns for the corner configuration have been taken for corner angles from  $10^\circ$  to  $270^\circ$  and for dipole-to-corner spacings of 0.1 to 3 wavelengths. Both  $H$ -plane and  $E$ -plane patterns are shown for each configuration employing semi-infinite sheet sides.

Certain specific corners have been investigated for the effects on pattern of finite side lengths and side height, and integration patterns run to compute absolute gain of the units. Effects of spines and spacing of grid construction are investigated.

## 126. AN OMNIDIRECTIONAL SLOT ANTENNA ARRAY

A. J. HOEHN AND S. I. COHN

(Armour Research Foundation, Chicago, Ill.)

A longitudinally-polarized, omnidirectional antenna array is described in which the elements are formed from a coaxial line by slots running around the periphery of the outer conductor. The complete unit consists of a four-element, colinear, broadside array designed to operate at 2,500 megacycles per second. It is approximately 14 inches long, has a diameter of  $\frac{1}{4}$  inch including radome, and is strong, lightweight, and adaptable to low-cost manufacture. The array is capable of handling an average power of at least ten watts and has a power gain greater than four.

## SYMPOSIUM

## UHF Receivers I

(Organized by Professional Group on Broadcast and Television Receivers)

Chairman, D. E. HARNETT

(General Electric Company, Syracuse, N. Y.)

## 127. UHF HYBRID RING MIXERS

W. V. TYMINSKI AND A. E. HYLAS

(Allen B. DuMont Laboratories, Inc., Passaic, N. J.)

Application of hybrid rings to mixers reduces local oscillator radiation and noise, suppresses radio-frequency interference, decreases cross-modulation products, and provides a degree of high-pass filter action. In the 470 to 890 mc band the performance of hybrid ring mixers followed by low-noise IF amplifiers, compares favorably with RF amplifiers and conventional mixers.

A practical low cost uhf hybrid ring mixer has been developed which overcomes size and bandwidth limitations. Data on uhf hybrid ring performance will be presented, and comparisons will be made with other uhf receiving methods.

## 128. UHF TUNERS

M. F. MELVIN

(P. R. Mallory & Co., Inc., Indianapolis, Ind.)

The problems encountered in uhf tuning and conversion can best be met through the use of a continuous tuner. The techniques of application of circuitry to a continuous tuner of the variable-inductance type, yield simpler solutions than are obtainable with other methods of tuning. This continuous tuning technique lends itself to uhf converter application as well as vhf-uhf "front end" design.

## 129. THE DESIGN AND PERFORMANCE OF A COMPACT UHF TUNER

H. F. RIETH

(Kingston Products Corporation, Kokomo, Ind.)

A uhf converter or tuner continuously covering the frequency range of 470-890 mc, using curved tuned lines as a basic tuning device, is described. The mechanical design lends itself to the small basic package with simplicity of production and alignment. Mechanical layout and microwave measurement technique will be briefly described. The design is primarily intended for use as a uhf converter or as a tuner in a television chassis. Performance data and curves will be submitted.

## 130. A UHF-VHF TURRET TUNER FOR TELEVISION RECEIVERS

ALBERT COTSWORTH, MAX BEIER, JOHN BELL AND JAMES WHITE

(Zenith Radio Corporation, Chicago, Ill.)

A turret-type tuner capable of both uhf and vhf reception has been described. A new tuner of this type is described which combines small size, ease of strip replacement, good performance, low radiation, and low cost.

## 132. AN SI-CHANNEL TURRET TUNER

J. M. SCANDURA

(Krisman Instrument Corporation,  
Elmhurst, N. Y.)

Experiments have been conducted to determine the feasibility of discrete channel selections in the vhf range similar to that presently used by most vhf tuners. The paper presents the engineering problems and describes some of the unsuccessful attempts as well as the reasons for choosing the final circuitry and mechanical arrangement. A discrete channel vhf tuner covering all television channels will be discussed in detail. The paper covers the turret problems, vacuum tube problems, characteristics of the vhf-vhf tuner (noise figure, image rejection, etc.) and the fundamental aspects of probability of successful reception under field conditions. Due to the many possible solutions, the development of the SI-channel turret tuner will discuss the technical, economical and field requirements. The characteristics of a turret tuner as compared to a continuously tunable structure will be analyzed. Photographs of experimental tuners utilizing these principles and measurements of performance will be presented.

## 132. RF PERFORMANCE OF A NEW UHF TRIODE

H. W. A. CHALSBURG

(General Electric Company,  
Schenectady, N. Y.)

This paper is being presented in conjunction with the paper "A UHF Amplifier Tube for Television Tuners" which will be presented in the technical session on Small High-Frequency Tubes.

The details of techniques of measurements and the dynamic results obtained with the uhf triode will be discussed. Performance characteristics in the vhf and uhf television bands will be covered, and a comparison of gain and noise figures will be made with tubes now available for vhf amplifier service.

## Circuits IV

Chairman, L. A. ZADEH

(Columbia University, New York, N. Y.)

## 133. DISPERSION IN TRANSMISSION SYSTEMS

M. J. DE TORO

(Federal Telecommunications Laboratories,  
Natick, N. J.)

The novel quantum methods of Gabor show intuitively satisfying formulations for delay and dispersion of the impulse transient response of transmission systems whose amplitude and phase steady-state transfer characteristics are neither flat nor linear. Dispersion or pulse lengthening in the impulse transient response results from the weighted phase distortion and from ripples or mean-square fluctuations in amplitude response. In all transmission systems, dispersion gives rise to intersymbol interference and consequent limitation in the amount of transmissible information.

## 134. NETWORK SYNTHESIS FOR SPECIFIED TRANSIENT RESPONSE

W. H. KAUFF

(Stanford Research Institute,  
Stanford, Calif.)

Three methods for the synthesis of finite, lumped-parameter networks for the case in which the desired behavior is prescribed in transient terms rather than the more usual frequency (gain and/or phase) characteristics will be presented. Refinements on the already-known "time-domain" approach, certain time-frequency-domain relationships which permit a "frequency-domain" approximation while retaining control over the network transient response, and a new method employing both time- and frequency-domain approximations, form the basis for the procedures.

## 135. TRANSFORMS FOR LINEAR TIME-VARYING NETWORK FUNCTIONS

J. A. ASELTINE AND D. L. TRAUTMAN

(University of California,  
Los Angeles, Calif.)

Methods for finding integral transformations appropriate for linear time-varying systems will be discussed. These transformations reduce the differential equations describing the variable system to algebraic ones. Many features of the Laplace transform method for fixed systems have counterparts. In particular, these transforms lead to a "system function" through which analysis and synthesis methods can be formulated. Theorems and tables of transform-pairs are developed for systems with two kinds of parameter variation. This procedure facilitates, for example, synthesis of networks having a transient response of the form  $t^n$  if  $L$  and  $C$  vary as  $t$ , and  $(\sin bt)/t$  if  $R$  varies as  $1/t$ .

## 136. PARALLEL-TUNED CIRCUIT PERIODICALLY SWITCHED TO A DC SOURCE

L. J. GACOLETTO

(Radio Corporation of America,  
Princeton, N. J.)

A parallel-tuned circuit periodically connected to a source of linear direct-current energy (e.g., by means of an electron tube or switch) is fundamental to a large group of energy conversion circuits. A complete analysis embraces many voltage and current variations including sinusoidal, saw-tooth, and more complex wave shapes depending upon circuit parameters and switch period. The analytic results can be used to analyze sinusoidal and nonsinusoidal oscillators, class-C amplifiers, and many pulsed circuits.

## 137. A HIGHLY ACCURATE VARIABLE TIME DELAY SYSTEM

Y. P. YU

(Allen B. DuMont Laboratories,  
Clifton, N. J.)

A variable time-delay system having time jitter less than 0.0001 microsecond, equivalent to 2.5 parts per million of its maximum time delay, will be described. Bilateral elements and distributed amplifier to compensate losses are used. The signal

pulse travels through each delay element many times to increase total time delay. An experimental unit having total time delay up to 100 microseconds in steps of one microsecond has been satisfactory. Usual causes of time jitter such as variations of cutoff characteristics, noise, hum, and fluctuations of supply voltages, cannot affect the accuracy of the system.

## 138. RC TIME DELAY CIRCUIT OF VERY HIGH TIME CONSTANT

R. G. ROUSH

(The Johns Hopkins University,  
Baltimore, Md.)

Performance of the cathode-follower circuit in timing applications in which its input impedance is used in conjunction with a capacitor to give a high effective time constant without prohibitively large component values will be analyzed. The simple cathode-follower circuit may be incorporated into any resistance-capacitance timing circuit using the differentiator configuration common to the multivibrator. Such a circuit will permit the monostable multivibrator to be used for the generation of adjustable delay periods of many minutes with good accuracy for most applications.

Electron Tubes I—  
Power and Gas  
Tubes

Chairman, DAYTON ULREY

(Radio Corporation of America,  
Harrison, N. J.)

## 139. METHOD FOR PREDICTION OF MAGNETRON CHARACTERISTICS RELATING FREQUENCY AND OPERATING ANODE VOLTAGE TO POWER OUTPUT

H. W. WELCH, JR.

(University of Michigan,  
Ann Arbor, Mich.)

An approximate method has been developed for determining the shape and density of the spokes of electronic space charge when large rf potentials exist in the magnetron. With the estimation of space-charge configuration which this method makes possible, induced current theory and resonant circuit analysis can be applied to calculate frequency-power and operating anode potential-power characteristics. Relatively simple equations for these characteristics are presented. Characteristics for typical values of the variables of magnetron design are given. The theory has been applied to experimental data with reasonably good argument.

## 140. A NEW PULSE KLYSTRON AMPLIFIER FOR THE 960-1,215 MC REGION OF AIR NAVIGATION AIDS

C. VERONDA

(Sperry Gyroscope Company,  
Great Neck, N. Y.)

A pulse klystron amplifier, capable of delivering over 20 kilowatts of peak power with a gain of over 200 times, is described. The design concepts and the salient points of the development are discussed.

This three-resonator cascade amplifier was designed to be used as the final stage of the ground transponder in the Civil Aeronautics Authority's Distance Measuring Equipment. The klystron is "space-charge" focused, and is designed for use with a duty cycle which is variable from zero up to 1%. Because of the unusual beam requirements in this tube, the bunching voltage required is comparatively high. Therefore, the measurements on this tube are of special interest.

#### 141. UHF POWER TUBES

P. T. SMITH

(Radio Corporation of America,  
Princeton, N. J.)

The relative performance of structurally equivalent triodes and tetrodes have been determined with wide-band circuits at uhf. Most of the data was obtained with 5 kw peak power, silver-soldered ceramic envelope insulated triodes with grounded grid circuits. The performance of the triodes shows good agreement with large signal theory. At 900 mc the transit time loading of the grid, with normal tetrode operation, exceeds that of the grounded grid triode when the cathode-to-grid spacing is 0.015 inch and the grid-to-screen is 0.035 inch. With 5 kw output the performance of the triode at 900 mc is comparable with that at low frequencies, merely requiring large electron emission densities.

#### 142. HIGH-FREQUENCY PERFORMANCE OF ELECTRON MULTIPLIERS

R. R. LAW, D. A. JENNY AND F. H. NORMAN  
(Radio Corporation of America,  
Princeton, N. J.)

Design features and performance data of a developmental power electron multiplier intended to give several kilowatts output at frequencies up to 900 megacycles will be described. The poor performance of this tube at higher frequencies led to a critical study of other developmental multi-stage electrostatic electron multipliers. These tests will also be described. To explain the results it is suggested that secondary electron emission exhibits a simple exponential decay characteristic with a time constant of about  $3 \times 10^{-10}$  second. The engineering aspects of such a fundamental limitation to the high-frequency performance of practical electron multipliers will be discussed.

#### 143. FACTORS AFFECTING THE LIFE OF HYDROGEN THYRATRONS

M. R. ZINN

(Signal Corps Engineering Laboratories,  
Fort Monmouth, N. J.)

The life of a hydrogen thyratron in a line-type modulator circuit is a function of the various circuit parameters in the grid and plate circuits. With the grid circuit conditions maintained constant, it is found that the average life of the tubes under various conditions of the plate circuit can be correlated with three dissipation factors: the power dissipated in the plate during the pulse, the power dissipated in the plate during the inverse voltage, and the power dissipated in the cathode due to the passage of pulse current. These factors have been successfully correlated with the results of life

tests. The results of the analysis indicate the circuit parameters to be controlled by the application engineer and the tube characteristics of interest to the tube manufacturer.

## Radar and Radio Navigation

Chairman, H. BUSIGNIES

(Federal Telecommunication Laboratories,  
Inc., Nutley, N. J.)

#### 144. DESIGN OF SMALL RADAR LINE-TYPE MODULATORS WITH AC CHARGING CIRCUITS

J. F. CLAYTON AND S. J. KRULIKOSKI, JR.  
(Bendix Aviation Corporation,  
Detroit, Mich.)

The use of a dc driven inductor-alternator and hydrogen thyratron switch permits the construction of compact ac charging pulse modulators with repetition frequencies up to several thousand pulses per second. The high output impedance of the inductor-alternator is used as the charging inductance with a low leakage reactance step-up transformer. The hydrogen thyratron is automatically phased and triggered from a non-linear coil in the charging circuit, no tubes being required. The dc drive on the inductor-alternator may result in some variation in the frequency of the ac voltage. Curves are presented showing the charging voltage step-up ratio as a function of circuit  $Q$  and applied frequency for the cases of one and two cycle charging. Over-voltage protection by means of circuit tuning is discussed briefly.

#### 145. A HIGH QUALITY PICTURE DISPLAY UNIT

R. T. PETRUZZELLI

(Allen B. DuMont Laboratories, Inc.,  
Clifton, N. J.)

The units described in this paper are high quality television monitors developed primarily for use in an electronic display system, providing bright television pictures of airport surveillance radar and mapping information. The equipment provides a simultaneous display of the above information on a bright display console at a brightness level sufficient for operational use in an airport traffic control tower.

The unit incorporates highly linear sweeps with good over-all focus and a high-light brightness of 60 foot-lamberts. The video amplifier has a bandwidth of 8 megacycles, with very good low-frequency response, provided by the use of keyed diode clamp circuits.

#### 146. ANALYSIS OF AN AUTOMATIC RADAR RANGE-TRACKING SYSTEM

E. F. GRANT

(W. L. Maxson Corporation,  
New York, N. Y.)

An analysis is made of a conventional automatic radar range-tracking system to determine the relationship between indicated range jitter due to noise and the system parameters and signal-to-noise ratio. In particular, it is shown for an intermediate-frequency amplifier with a gaussian frequency characteristic (approached by a synchronous-tuned or linear phase-shift

amplifier) that there is a bandwidth which will minimize the jitter due to noise for a fixed signal power.

The method used is that of tracing the power spectrum of white thermal noise through the IF amplifier, detector, integrators, boxcar generator and servo amplifier (closing the loop), and finally integrating the power spectrum of indicated range for a fixed target to find the mean-square error in indicated position.

#### 147. THE WIND-FINDING RADAR SYSTEM

A. D. EMURIAN

(Signal Corps Engineering Laboratories,  
Belmar, N. J.)

The Wind-Finding Radar System comprises the 3 cm Automatic Tracking Radar Set AN/CPS-10(XE-1) with its automatic wind computer and the windborne balloon-target train.

This paper outlines the evolution of the system into its present form; describes the basic features which fit it uniquely to the task of charting upper air winds with meaningful accuracy, quickly and cheaply; lists its essential technical and operational characteristics and relates them to the governing objectives which dictated its development.

Mention is made of present development to increase the system's wind-altitude capability and accuracy, to simplify it, and to balance the system package.

#### 148. POWER REQUIREMENTS FOR LONG-RANGE NARROW-BAND NAVIGATION SYSTEMS IN THE LOW-FREQUENCY BANDS

N. MARCHAND, A. JACOBS, D. CAWOOD  
(Sylvania Electric Products, Inc.,  
Bayside, N. Y.)

Calculations of radiated power requirements for various distances are made for the frequency range 0.1 to 2.0 mc. Generalized curves are given for various signal-to-noise ratios, using nighttime noise. Correction factors for the different latitude zones are included. The curves are drawn for one cps bandwidth, but since the power will be directly proportional to the bandwidth, they are transferable to any usable system. Ground constants are taken from  $\sigma = 2 \times 10^{-14}$  to  $\sigma = 5 \times 10^{-11}$  emu, with  $\epsilon$  varying from 10 to 80. The equations used for these curves are derived from the surface-wave equations given by K. A. Norton. Ground-to-ground transmissions were used. Curves for height-gain factors beyond line-of-sight are given to allow transformation of the charts for use at various heights beyond line-of-sight.

## SYMPOSIUM

## Magnetic Core Memory Devices for Digital Computers

(Organized by Professional Group on  
Electronic Computers)

Chairman, C. V. L. SMITH  
(Office of Naval Research,  
Washington, D. C.)

#### 149. AN ANALYSIS OF MAGNETIC DELAY LINE OPERATION

E. A. SANDS  
(New York, N. Y.)

Since the first publication of the Harvard Computation Laboratory Progress Reports, there has been considerable interest in the use of magnetic components in digital computers and business machine systems. Particular interest has centered around the use of magnetic delay lines as a word-storage medium in a large scale, low access time internal memory. The difficulty in the design of magnetic delay lines (and magnetic components under current pulse conditions, in general) has been in representing the input impedance of a magnetic core by a simple analytical expression. In this paper, a simple equivalent input impedance of a magnetic core under current pulse conditions is derived, and this equivalent impedance is used in the analysis of the operation of a magnetic delay line.

#### 150. DESIGN OF A HIGH-SPEED SHIFT REGISTER USING MAGNETIC BINARIES

MAX FISHMAN  
(Transducer Corporation, Boston, Mass.)

The availability of highly oriented nickel-iron alloys has resulted in a greatly increased interest in the application of magnetic materials in static memory devices. However, for high-speed applications, the use of highly oriented magnetic alloys has created many problems. At the expense of slightly more complicated circuitry, it is often possible to use non-square-loop material in the memory device and thus effect a large increase in speed of operation. An example of such circuitry is described for an application in a high-speed shift register which can be designed around magnetic ferrite cores or ultra-thin magnetic tape-wound cores.

#### 151. MAGNETIC MATRIX SWITCHES

K. H. OLSEN  
(Massachusetts Institute of Technology, Cambridge, Mass.)

A matrix switch using ferromagnetic cores as nonlinear elements is a straightforward solution to many pulse switching problems that are difficult or impossible with a crystal matrix switch. Besides having arbitrary input and output impedances, it is often more efficient and useful than its crystal counterpart because power is supplied only to the selected output. The magnetic core is inexpensive, rugged, and apparently reliable for an indefinitely long life.

A pair of these switches is being developed for use with a multi-dimensional magnetic-ferrite memory where they will significantly decrease the required number of vacuum tubes and crystal diodes.

#### 152. STATIC MAGNETIC MATRIX MEMORY AND SWITCHING CIRCUITS

J. A. RAJCHMAN  
(Radio Corporation of America, Princeton, N. J.)

Information bits are stored in terms of the direction of magnetization of a multitude of saturated cores connected in a

matrix array. Access to any core, for registry or interrogation, is by simultaneous excitation of its defining matrix lines. Bi-valued signals, identifying the information bit and corresponding core, select these lines by activating magnetic switches, likewise composed of saturable cores. This memory is characterized by an access time of several microseconds, indefinitely long storage requiring no holding power, and the possibility of large storage capacity at low cost. Results with experimental models of 256 cores will be discussed.

#### 153. THE FERRO-RESONANT FLIP-FLOP

CARL ISBORN  
(Computer Research Corporation, Hawthorne, Calif.)

The bi-stable nature of the ferro-resonant circuit has been utilized to produce flip-flops which count at rates of 100,000 pulses per second. These flip-flops are composed of reactive elements and, therefore, consume little power. At the same time they are amplifiers and, therefore, are capable of delivering considerable sustained power into a load; thus, enabling them to drive indicator lights, diode or resistor matrices, operate relays, etc.

Two inputs and two outputs are provided in these flip-flops. Thus, either single-input carry-type binary counters, or double-input parallel gated counters may be constructed.

### Antennas II—Micro-wave A

Chairman, A. G. FOX  
(Bell Telephone Laboratories, Inc., Holmdel, N. J.)

#### 154. GAIN OF ELECTROMAGNETIC HORNS

E. H. BRAUN  
(Naval Research Laboratory, Washington, D. C.)

Recent experimental evidence indicates that the measured gain of pyramidal electromagnetic horns may be considerably in error if the measurements are carried out at short distances, and the aperture to aperture separation between horns is used in the gain formula:  $G = (4\pi R/\lambda) \sqrt{P_R/P_T}$ .

Further experimental verification of this effect has been obtained, and a theory has been developed which is in good quantitative agreement with present experimental data and demonstrates the physical reasons why the previous "far field" criterion of  $2D^2/\lambda$  is invalid.

Pending further experimental confirmation of the theory, curves will be calculated from which the error in gain measured at any distance may be obtained and applied as a correction.

#### 155. A RAPID-SCAN CIRCULARLY SYMMETRICAL PILLBOX ANTENNA

WALTER ROTMAN  
(Air Force Cambridge Research Center, Cambridge, Mass.)

An X-band antenna capable of high speed scanning through  $360^\circ$  by rotation of a small central hub, with a beam narrow in

azimuth and shaped in elevation, is described. Construction is of the waveguide-fed, double-layer pillbox type, but with a circular radiating aperture instead of the customary linear one. Spherical aberration of the antenna is markedly reduced by a circularly symmetric dielectric lens and/or multiple waveguide feeds. The elevation pattern is adjustable to some extent by surface-wave techniques making use of metal-backed dielectric or corrugations. Continuous scan as well as simultaneous scan in several directions is possible. The antenna may be either flush-mounted or enclosed within a radome. Constructional details and applications are discussed.

#### 156. METHOD FOR SIDE-LOBE REDUCTION

C. J. SLETTEN  
(Air Force Cambridge Research Center, Cambridge, Mass.)

A method is shown for compounding primary feeds in the focal region of microwave lenses and reflectors in order to modify the secondary pattern of high-gain systems. The basic idea is to examine the field structure produced in the focal region of a lens or reflector when it is illuminated by a plane wave, and to tailor the primary feed to this field structure. The main object has been to reduce side-lobe levels while preserving as much as possible of the gain and beam width.

Experimental models used to produce side lobe lower than 20 db down on a spherical reflector are described. The method of beam shaping described here can be used to advantage in a wide variety of antenna applications.

#### 157. TOLERANCES ON PARABOLOIDAL REFLECTORS

JOHN RUZE  
(Massachusetts Institute of Technology and Air Force Cambridge Research Center, Cambridge, Mass.)

The effect of mechanical deviations from a parabolic surface on the antenna gain and on the side-lobe level are analyzed. It is assumed that these mechanical errors are randomly distributed over the reflector surface with a known or measurable mean-square error. The far field radiation pattern is expressed as the transform of the autocorrelation function of the aperture distribution. Analysis indicates that on a statistical average the undistorted pattern is modified by the addition of spurious radiation whose angular distribution depends on the error correlation interval, and whose magnitude is proportional to the mean-square error and to the square of the correlated interval. Graphs will indicate the expected side-lobe level and the resulting reduction in gain.

#### 158. DESIGN OF DIELECTRIC WALLS FOR OPTIMUM TRANSMISSION

R. M. REDHEFFER  
(University of California, Los Angeles, Calif.)  
AND  
B. GOLVIN  
(Hughes Aircraft Company, Culver City, Calif.)

Optimum design of a dielectric wall is discussed in terms of minimizing the number

of parameters whose values must be specified arbitrarily. The case of the symmetrical three-layer sandwich wall is discussed rather completely. Such factors as transmission and reflection, dipolarization, and incidence-angle bandwidth are considered. We obtain expressions for optimum values of linear dimensions and dielectric constants for the cases where (a) there is only a single polarization, and (b) the dipolarizing effect of the dielectric wall must be considered. Tolerances are discussed in terms of transmission (or reflection) and phase contours; analytical and graphical means are given by which tolerances may be estimated. A set of design curves is given for sandwich walls, covering the range of dielectric constants thought to be physically realizable.

## SYMPOSIUM UHF Receivers II

(Organized by Professional Group on  
Broadcast and Television Receivers)

*Chairman, D. D. ISRAEL*

(Emerson Radio and Phonograph Corporation,  
New York, N. Y.)

### 159. PRACTICAL TV ANTENNAS FOR UHF RECEPTION

*E. O. JOHNSON*

(RCA Victor Division, Camden, N. J.)

AND

*J. D. CALLAGHAN*

(RCA Service Company, Inc.,  
Camden, N. J.)

Requirements for the reception of television signals on the ultra-high-frequency, or uhf, band (470–890 mc) are much the same in many respects as on the existing very-high-frequency, or vhf band (54–216 mc). For the more difficult fringe areas, or locations where reflections are severe, special types of antennas are needed, just as they are in vhf. Of the wide variety of special uhf antennas designed and tested by RCA engineers and RCA Service Company technicians during field tests in Washington and Stratford, near Bridgeport, Conn., from 1948 to the present, several types have proved so outstanding in their simplicity, economy, and performance, that it is felt they will find additional widespread use where maximum performance and reliability are the customer's primary considerations.

### 160. AMPLIFIERS FOR UHF DISTRIBUTION SYSTEMS

*T. MURAKAMI*

(RCA Victor Division, Camden, N. J.)

A theoretical and experimental study has been made of the use of single channel grid-separation amplifiers in ultra-high-frequency television distribution systems. The theoretical gain and noise figure curves for several currently available tubes are shown with the corresponding experimental curves. The over-all noise figure of an amplifier followed by a receiver or another amplifier is calculated for various gains and noise figures for the first amplifier. Curves of over-all gain and noise figure of a distribution system consisting of a single tube feeding a multiple number of tubes is shown, assuming equal distribution of power to each of the driven tubes. An experimental distribution am-

plifier using lumped circuit constants and coupled circuits is described.

### 161. COMPARISON OF PRESENT-DAY UHF AND VHF TELEVISION RECEIVERS

*R. A. VARONE*

(Admiral Corporation, Chicago, Ill.)

A comparison of present-day television receivers will be made from the point of view of their noise figure. These figures will be interpreted in more commonly used laboratory terminology, and resulting differences in reception will be discussed. Present limitations of uhf receivers and the probable need of new electronic tools will be indicated.

### 162. ROUND-TABLE DISCUSSION: RELATIVE ASPECTS OF THE VARIOUS METHODS OF UHF TUNING

*Moderator, LEWIS WINNER*

(Television Engineering, New York, N. Y.)

*Introductory Remarks, W. B. WHALLEY*

(Sylvania Electric Products Inc.,  
Bayside, N. Y.)

## Feedback Control

*Chairman, G. S. BROWN*

(Massachusetts Institute of Technology,  
Cambridge, Mass.)

### 163. STABILITY THEOREMS FOR FEEDBACK SYSTEMS

*J. F. KOENIG*

(National Bureau of Standards,  
Washington, D. C.)

Eight stability theorems which give new aspects of design of linear feedback systems will be presented. Five enter a new design method called the "root-trajectory" method which gives information not obtainable from any other method of feedback system synthesis. The root-trajectory method gives the trajectories of the roots of any  $n$ th order characteristic equation as two or three interesting parameters are varied simultaneously in any arbitrary manner.

### 164. STABILIZATION OF NONLINEAR FEEDBACK CONTROL SYSTEMS

*R. L. COSGRIFF*

(Ohio State University Research  
Foundation, Columbus, Ohio)

Often the desired static relationship between output and input of a system is a nonlinear function. Corresponding function generators can be made quite accurate by feedback; however, such systems cannot be stabilized in the same manner as is common for linear systems. A method of stabilization using perturbation techniques has been developed which effectively linearizes these nonlinear systems. This method is an extension to the conventional methods used in the analysis of linear systems. Other nonlinear systems, which cannot be stabilized by linear methods, can frequently be stabilized by the method developed.

### 165. RATE-LIMITED CONTROL SYSTEM NOISE

*I. H. VAN HORN AND R. G. WILSON*

(Goodyear Aircraft Corporation,  
Akron, Ohio)

The effects of noise in rate-limited stabilization systems have been studied using analytical, topological, and simulation techniques. Simulation has been found to yield results agreeing very satisfactorily with those obtained by other means. Nonlinear techniques used in the simulation will be presented. This study shows the importance of considering the effects of noise in the design of rate-limited closed-loop systems.

### 166. EXPERIMENTAL STUDIES ON SERVOMECHANISMS

*A. V. COHEE*

(Navy Department, Indianapolis, Ind.)

Laboratory equipment for the study of instrument servomechanism response and measurements on servos having common ailments will be discussed. Nonlinear effects, of little importance in high-power servos, can cause serious errors in some cases. Equipment to be described was designed for accurate evaluation of high-speed, high-accuracy instrument servos under dynamic conditions. Examples of nonlinear effects include errors at creep velocities, errors due to nonlinear error signals, and double-valued frequency response.

### 167. AFC SYSTEM ANALYSIS BY ELECTROMECHANICAL ANALOGUE

*D. LEED*

(Bell Telephone Laboratories, Inc.,  
Murray Hill, N. J.)

In measurement set applications and in communication systems, frequent use is made of automatic frequency-control devices. The operation of commonly employed circuits for automatic frequency control will be analyzed from the viewpoint of the (electrical frequency: angular velocity) mechanical analogue. Concepts of lock-in range, the effect of detector time constant and of strains imposed on the frequency control loop will be discussed.

## Electron Tubes II— Small High-Frequency Tubes

*Chairman, E. F. CARTER*

(Sylvania Electric Products Inc.,  
New York, N. Y.)

### 168. A HIGH-GAIN KLYSTRON AMPLIFIER FOR RELAY SYSTEMS

*G. BERNSTEIN*

(Sperry Gyroscope Company,  
Great Neck, N. Y.)

A 3-cavity klystron amplifier (SAC-41) operating at 4,000 mc has been developed to meet the needs of microwave relay work. The tube will provide 10 watts of output power at an anode potential of 700 volts and has a power gain of 30 db. It was developed to overcome the fading problem in microwave relay link transmission. It is tunable over the common-carrier band of 3,700–4,200 mc and features an ion-focussed high-current beam which makes possible a low operating voltage. Performance is centered so that there is less than a 1 db drop in power output at the ends of the tuning range. The tube is adaptable to high-gain wide-band operation as either a power amplifier or a high-level mixer.

### 169. FM DISTORTION IN REFLEX KLYSTRONS

THEODORE MORENO AND R. L. JEPSEN  
(Varian Associates, San Carlos, Calif.)

A theoretical and experimental study of the distortion properties of reflex klystrons will be reported. This study is particularly concerned with FM application of these tubes. These distortion properties are of particular importance when reflex klystrons are used in FM relay or transmitter service. A novel experimental method has been devised to measure the absolute value of FM distortion. These measurements agree very well with the theoretical calculations. Design techniques for reflex klystrons of minimum distortion will be discussed.

### 170. THE MEASUREMENT OF CATHODE INTERFACE IMPEDANCE

H. B. FROST  
(Massachusetts Institute of Technology, Cambridge, Mass.)

Cathode interface impedance may be encountered in vacuum tubes after several thousand hours of life when alloys containing considerable silicon are used for cathode base material. This impedance may be measured by a new method which gives greatly improved accuracy and which uses a transconductance bridge in conjunction with a resistance-inductance network whose impedance complements the equivalent resistance-capacitance network of the interface impedance. At least two time constants (0.1 to 0.5 microsecond and 0.5 to 3.0 microseconds, respectively) are associated simultaneously with the interface impedance. An associated potential barrier between 1 and 2 electron volts has been measured.

### 171. UHF AMPLIFIER TUBE FOR TELEVISION TUNERS

C. E. HORTON AND HSIUNG HSU  
(General Electric Company, Owensboro, Ky.)

A nine-pin miniature grounded-grid amplifier tube has been developed to operate as the radio-frequency amplifier in uhf television tuners. Satisfactory gain, bandwidth, and noise characteristics and good isolation between input and output circuits are obtained throughout the 470-890 megacycle band.

This paper treats the special problems encountered in this development and discusses the methods employed in arriving at a useful solution. The techniques of the measurements involved in the development of this tube are discussed in detail.

### 172. MICROWAVE CONVERSION AND DETECTION EMPLOYING ELECTRON TUBES

A. B. BRONWELL, J. MAY, AND I. C. NITZ  
(Northwestern University, Evanston, Ill.)

Experiments on vacuum tubes as detectors and converters of modulated microwave signals have shown that these have low noise levels and greater sensitivity than crystal detectors. The principle of operation is different from that of the conventional operation of vacuum tubes. In conventional tubes, the electron transit time is a small fraction of the period of the ac wave. The

tubes to be described here have large transit times, often exceeding several times the period of the ac wave. Also, the microwave signal is radiated into the interelectrode space, instead of being applied to the tube terminals.

Solutions of the resulting electron dynamic equation will be presented in graphical form for several typical cases.

## SYMPOSIUM

### The Integration of Electronic Equipment with Airframe Design

(Organized by Professional Group on Airborne Electronics)

Chairman, L. B. HALLMAN, JR.  
(Wright Air Development Center, Dayton, Ohio)

### 173. THE INTEGRATION OF ELECTRONIC EQUIPMENT WITH AIRFRAME DESIGN

A. F. COOMBS AND C. W. DIX  
(General Electric Company, Syracuse, N. Y.)

Progress in co-ordinating the design of airborne radar equipment with the airframe is discussed, emphasizing such basic design characteristics as accessibility, form factor, heat dissipation, altitude, shock, vibration, rf noise, and primary power supply. A review of the scope of present-day installation problems follows, giving specific examples of co-ordinated design. Suggestions for improving current design practices include an early exchange of information among all agencies concerned, close liaison as the design unfolds, and throughout, an appreciative understanding of each other's problems.

### 174. THE UNIQUE AIRPLANE ENVIRONMENT EFFECT ON ELECTRONIC EQUIPMENT

D. T. GEISER  
(Boeing Airplane Company, Wichita, Kan.)

Effects of altitude, temperature, and humidity are reviewed as individual problems, and the results are compared to typical high-performance airplane environment. Transitions of environment are shown as important as static environment and require special design care. Some design precautions are discussed. Brief environment transition testing is shown useful as a design tool.

### 175. ELECTRONIC COMPONENTS FOR AIRBORNE REQUIREMENTS

F. E. WENGER  
(Wright Air Development Center, Dayton, Ohio)

This paper describes the environmental space factor, and reliability requirements of airborne electronic component parts. The parameters for these requirements are described and the need for them substantiated. Approaches being used to solve some of the problems are described, as well as the general trends along which component development should be directed. The purpose of this paper is to present the importance of the availability of adequate component parts for airborne electronic equipments, and the philosophy

upon which their future development should be based.

### 176. HEAT DISSIPATION FROM AIRBORNE ELECTRONIC EQUIPMENT

LOUIS POSSNER  
(Hughes Aircraft Company, Culver City, Calif.)

This paper will present a brief discussion of the over-all problem, the reasons for the present interest, and review of research in this field. Design criteria for the dissipation of heat from electronic equipment will be presented, weight and power requirements of cooling systems will be discussed, and various methods will be compared. The advantages and disadvantages of high operating temperatures will be given, and need for higher operating efficiencies will be shown.

## Digital Computers

Chairman, J. G. BRAINERD  
(University of Pennsylvania, Philadelphia, Pa.)

### 177. THE CADAC

W. E. DOBBINS

(Computer Research Corporation, Hawthorne, Calif.)

Recently a small electronic digital computer, known as CADAC, or CRC-102, has been constructed for the Air Force. The CADAC is a universal type computer, uses a three-address code, and operates in a binary fixed-point number system. The memory is a magnetic drum, with space for 1,024 words. Physically, the machine occupies a space of 2½ feet by 4½ feet, and is 5 feet high. Its weight is 500 pounds, mostly in the power supply. The small size and reduced number of components (180 tubes and 2,500 diodes) are the unique features of this computer.

### 178. ANALYSIS OF CONTROL SYSTEMS INVOLVING DIGITAL COMPUTERS

W. K. LINVILL  
(Massachusetts Institute of Technology, Cambridge, Mass.)

A digital computer operates on sampled signals. To analyze the operation of a computer in a control system which operates largely on continuous signals, one should describe sampling, desampling, and computer operation in familiar control-system terms.

Sampling is analogous to impulse modulation. The whole mixed system viewed in the frequency domain is analogous to a system having one part operating on direct signals and another part operating on suppressed-carrier amplitude-modulated signals. Desampling is like ripple filtering in demodulation, and linear computer operation can be characterized by transfer functions. Frequency analysis allows evaluation of the interaction between the computer and the rest of the system and intelligent adaptation of the computer into the system.

### 179. FREQUENCY ANALYSIS OF DIGITAL COMPUTERS USED IN CONTROL SYSTEMS

J. M. SALZER  
(Hughes Aircraft Company, Culver City, Calif.)

This paper discusses the analysis and synthesis of linear real-time digital-computer programs in the frequency domain. Such programs correspond to linear difference equations, and can be characterized in the frequency domain by a transfer function, which is rational in  $e^{-sT}$  (where  $e$  is the Napierian base of logarithm,  $s$  the complex frequency variable, and  $T$  the constant time interval of sampling). This contrasts with linear analog filters, whose transfer functions are rational in  $s$ .

Conventional techniques of frequency analysis are adaptable to digital filters: the amplitude, phase and locus of the program are defined, and stability can be studied in the complex plane. Synthesis of programs becomes as systematic as that of networks, and the method finds use in the design of computers, analog-digital systems, as well as numerical processes.

#### 180. A VERY RAPID ACCESS MEMORY USING DIODES AND CAPACITORS

A. W. HOLT

(National Bureau of Standards,  
Washington, D. C.)

An electrostatic memory for computers is described which utilizes the principle of regeneration to store binary information upon discrete capacitors, access being through two diodes. It seems possible to have fractional microsecond access for reading any digit in the matrix. Power efficiency is superior to other forms of electrostatic memory, and is mainly limited by present characteristics of germanium diodes. Emphasis is placed on the fact that only two-terminal devices are used in the memory proper, thus allowing promising design flexibility and minimum maintenance.

#### 181. THE CHARACTRON

J. T. MCNANEY

(Consolidated Vultee Aircraft Corporation,  
San Diego, Calif.)

The Charactron is a special-purpose cathode-ray tube incorporating a design which is unique among tubes of this type. A matrix containing character-shaped openings is located between the electron gun and the fluorescent screen. A stream of electrons directed through the matrix openings results in a shaped beam that provides a presentation of characters on the screen of the tube where they can be read or photographed.

Among the more general applications of the Charactron are: (1) data conversion and tabulation of analog or digital information, (2) computer readout, (3) high-speed printing, (4) high-speed communications, and (5) monitoring and message display equipments.

## Antennas III— Microwave B

Chairman, P. H. SMITH

(Bell Telephone Laboratories, Inc.,  
Whippany, N. J.)

#### 182. A MICROWAVE LUNEBOG LENS

G. D. M. PEELER, D. H. ARCHER,

K. S. KELLEHER

(Naval Research Laboratory,  
Washington, D. C.)

A two-dimensional microwave model of the Luneberg lens has been designed employ-

ing the TE<sub>10</sub> mode. It consists of two 36-inch-diameter, almost-parallel, conducting plates; the spacing between plates is filled with polystyrene and varies with the radius  $r$  to give the desired index of refraction  $n = \sqrt{2 - r^2}$ . Due to symmetry about the axis, this lens has radiation patterns with constant gain and good side-lobe level as a feed horn scans over the circumference. Experimental patterns in the two principal planes show good agreement with computed patterns.

#### 183. RADIATION FROM METAL-LOADED WAVEGUIDES TERMINATED IN A GROUND PLANE

R. E. WEBSTER AND M. H. COHEN

(Ohio State University Research  
Foundation, Columbus, Ohio)

Radiation from small apertures in a ground plane is considered. Measurements have been made on apertures excited by metal-loaded guides suitable for radiating circular polarization. Dielectric loading and combination metal-dielectric loading were also considered as schemes for reducing the cutoff frequency of the exciting waveguides. Parameters affecting bandwidth and aperture reflections are discussed, and experimental techniques for obtaining the effective aperture impedance are described. A method of calculating the aperture impedance from the guide dimensions for certain loading configurations is also presented.

#### 184. MUTUAL COUPLING BETWEEN SLOT RADIATORS

M. J. EHRLICH, C. W. CURTIS, AND  
R. FAWCETT

(Hughes Aircraft Company,  
Culver City, Calif.)

In the design of slot arrays with critical radiation patterns, mutual coupling between radiators is an important quantity. Application of Babinet's principle to P. S. Carter's relationships of the self and mutual impedance of parallel dipoles, and normalization of the data with respect to the feed waveguide, furnishes theoretical results. The self and mutual admittances of the two slots located on an infinite ground plane are measured as a function of slot separation and orientation. The theoretical and experimental values are in excellent agreement within the experimental error.

In addition, the coupling between two longitudinal shunt slots, displaced axially on the broad face of a rectangular waveguide, has been measured. The coupling is found to be a negligible magnitude as compared to variations due to manufacturing tolerances.

#### 185. OFF-AXIS CHARACTERISTICS OF PARABOLOIDS AND SPHERES

K. S. KELLEHER

(Naval Research Laboratory,  
Washington, D. C.)

Information is presented on the radiation patterns of paraboloids and spheres fed by a point source. A series of paraboloidal reflectors of various focal lengths, each 30 inches in aperture diameter, were evaluated at a wavelength of 3.2 cm. For each reflector an investigation was made of the patterns at various positions of feed horns in front of the reflector. Data was obtained on the gain,

beamwidth, and side-lobe level of the radiation patterns as a function of aperture illumination and  $f/D$  ratio. Other quantities evaluated included beam shift as a function of feed displacement and  $f/D$  ratio. A similar type of information was obtained from a series of spherical cap reflectors of various radii.

#### 186. A BROAD-BAND AXIALLY SYMMETRIC VERTEX FEED

F. L. HENNESSEY

(Naval Research Laboratory,  
Washington, D. C.)

A vertex feed, designed to illuminate a paraboloidal reflector antenna at microwave frequencies, is discussed. Certain advantages over vertex feeds presently in use are pointed out. A small splash plate of special geometry, placed at the end of a circular waveguide extending through the vertex of the reflector, directs the energy back onto the reflector and provides a match to space of  $VSWR < 1.5$  over at least a twenty per cent frequency band. The complete axial symmetry of the feed permits the use of either linear or circular polarization and provides mechanical advantages in narrow-angle rapid-scanning systems.

## Radio Communication Systems

Chairman, W. M. GOODALL

(Bell Telephone Laboratories, Inc.,  
Deal, N. J.)

#### 187. A RADIO RELAY SYSTEM EMPLOYING A 4,000-MC THREE-CAVITY KLYSTRON AMPLIFIER

J. J. LENEHAN

(Western Union Telegraph Company,  
New York, N. Y.)

This paper discusses the application of this tube as an amplifier in a relay system already in operation when the amplifier became available. The reasons for using the tube, the design necessary to incorporate it into existing circuitry, and its performance characteristics are described. The practical problems of tube alignment, life, and maintenance as encountered in system operation are discussed.

#### 188. AN FM MICROWAVE RADIO RELAY

R. E. LACY AND C. E. SHARP

(Signal Corps Engineering Laboratories,  
Fort Monmouth, N. J.)

The design features of an 8,000–8,500 mc radio relay are reviewed. The innovations described are the result of research and engineering accomplished for the design of a military radio relay system.

A mechanically and electronically tuned cw communications magnetron is included which provides a carrier power in excess of 50 watts, capable of being frequency modulated. A unique frequency stabilization circuit maintains the carrier center frequency, improves the linearity of the modulation, and greatly reduces the carrier-noise frequency variations by virtue of the inverse feedback introduced.

A novel duplexing antenna system, comprised of a waveguide hybrid tee, a wave-

guide mast structure, and off-center fed parabolic reflector antenna assembly, and a waveguide cavity preselector for the receiver are described.

#### 189. NONSYNCHRONOUS PULSE MULTIPLEX SYSTEM WITH RANDOM SAMPLING

J. R. PIERCE AND A. L. HOPPER  
(Bell Telephone Laboratories, Inc.,  
Murray Hill, N. J.)

This system uses the same frequency and approximately the same repetition rate for each transmitter. Pulse groups carrying samples from a given transmitter are "tagged" for identification at the receiver. Interferences between transmitters are reduced by sampling at random times. When pulses overlap, the receiver is disabled and the sample is lost. Noise due to lost samples is minimized by holding one sample until another is received.

Such a system allows an unlimited number of channel assignments in a given frequency band although only a limited number can be used simultaneously.

An experimental two-channel system was built and tested.

#### 190. EXALTED-CARRIER AND SINGLE-SIDEBAND DIVERSITY RECEIVERS

M. G. CROSBY  
(Crosby Laboratories, Mineola, N. Y.)

Recent developments are described which have resulted in two simplified receiving systems for long range communication. The first is a contact double-sideband exalted-carrier detector unit which may be connected to an ordinary communications-type receiver. The second is a single-sideband adapter unit useable in the same manner. The advantages of exalted-carrier detection and the problems involved in the change from double-sideband to single-sideband techniques are discussed. The requirements of a diversity combining system are outlined and a new type of exalted-carrier or single-sideband diversity combiner is described which provides optimum performance.

#### 191. COUNTER CIRCUIT FOR A BROADBAND MULTIPLEX RECEIVER

A. R. VALLARINO, H. A. SNOW, AND  
C. GREENWALD  
(Federal Telecommunication Laboratories,  
Nutley, N. J.)

Counter receivers, operating at one megacycle with a modulating frequency exceeding 150 kilocycles, were developed for frequency-division multiplex subcarrier systems. Harmonic distortion of less than 0.2 per cent is not critically dependent on the values of the passive (resistors and capacitors, only) and active elements. There are no tuning adjustments.

Each limiter stage employs a double-cutoff cathode-coupled triode to generate square waves having excellent symmetry between positive and negative halves and rise times shorter than 0.04 microsecond.

The counter-discriminator is a cathode-follower variation of previously used counters, and permits relatively small output tubes to be employed.

## Circuits V

Chairman, H. L. KRAUSS  
(Yale University, New Haven, Conn.)

#### 192. ANALYSIS OF MEASUREMENTS ON MAGNETIC FERRITES

C. D. OWENS  
(Bell Telephone Laboratories, Inc.,  
Murray Hill, N. J.)

Ferrites are unique nonmetallic materials with new combinations of magnetic, electric, and dielectric properties. For this reason, methods commonly used for measuring and expressing core loss coefficients in magnetic cores are not very satisfactory. Resonance type effects associated with frequency and dimensions are also present in ferrites. Measurements of permeability, magnetic  $Q$ , and dielectric properties versus frequency, temperature, and dimensions are discussed. The need for standardization of measurements and magnetic data for the convenient use of design engineers is brought out. The product  $\mu Q$  of the magnetic material is shown to be conveniently related to the quality factors of inductance coils and transformers. The  $\mu Q$  product measured on a closed magnetic core remains essentially constant when discrete air gaps are inserted for lowering permeability, and therefore is a useful and practical parameter for evaluating ferrite core materials to be used in assembled cores containing gaps.

#### 193. MAGNETIC AMPLIFIER PERFORMANCE ANALYSIS

D. LEBELL AND B. BUSSELL  
(University of California,  
Los Angeles, Calif.)

The analysis of magnetic amplifier circuits is facilitated and extended by application of the differential analyzer computer. Effects of magnetic hysteresis, rectifier leakage, and reactor nonlinearities have been studied for the parallel connected self-feedback amplifier.

As output data, the computer indicates the average value of load current and plots waveforms of current and flux. This data shows the shift in transfer characteristics due to hysteresis, the decrease in gain (slope or transfer curve) due to rectifier leakage, and the "rounding" of the transfer curve due to curvature of the magnetic characteristic. Results point to corrections which can be applied to improve the simplified analysis or design by compensating for these effects.

#### 194. BARIUM TITANATE PROPERTIES

A. I. DRANETZ  
(Gulton Manufacturing Company,  
Metuchen, N. J.)

Useful relative dielectric constants up to 6,000 can be realized by barium titanate ceramics, and the materials may be made to have a nonlinear dielectric constant, now being investigated for circuits such as modulators and dielectric amplifiers. The nonlinear materials exhibit a remanent polarization and can be used as the basis of various new memory devices.

The titanates also have piezoelectric characteristics. Instruments such as high-frequency accelerometers, ultrasonic transducers, microphones, phonograph pickups,

hydrophones, underwater projectors and displacement gauges are using these materials, and components such as acoustic delay lines are in development.

#### 195. A FERROELECTRIC AMPLIFIER

H. URKOWITZ  
(Philco Corporation, Philadelphia, Pa.)

"Ferroelectric" refers to nonlinear dielectrics characterized by a charge-versus-voltage relationship exhibiting hysteresis and dielectric saturation. A capacitor using barium-strontium titanate ceramic was used in a single-tuned circuit to which a high-frequency current was applied. A low-frequency signal was applied to the capacitor. The resulting amplitude-modulated high-frequency voltage was detected. Analysis shows conditions for maximum amplification. Power gains of about 60 were obtained.

With only the high-frequency voltage applied, the output of the amplifier was fed back to the input, and sustained oscillations of low frequency were obtained. Frequency of oscillation could be varied continuously over a wide range.

#### 196. GERMANIUM DIODE TRANSIENT RESPONSE

J. H. WRIGHT  
(National Bureau of Standards,  
Washington, D. C.)

Whisker-contact germanium diodes are valuable as fast switching devices because of their high forward conductance and low capacities. Since inherent limitations on switching speeds are not well known, experiments were made to study recovery times after 0.03 microsecond switching transients from: (a) forward to back, (b) back to forward, (c) neutral to back, and (d) neutral to forward conduction. Quite serious effects occur for (a) and (b), which are the important cases for computer and other switching applications. Conductances vary by factors of 3.0 to 10.0 times normal, with 0.5 to 1.0 microsecond for 90 per cent recovery. The mechanism will be discussed and transient tests recommended.

#### 197. GERMANIUM DIODE TESTING PROGRAM

D. J. CRAWFORD AND H. F. HEATH  
(International Business Machines  
Corporation, Poughkeepsie, N. Y.)

This paper will present a review of an extensive germanium diode testing program. A discussion of the various type-approval and production tests is given along with the means for effecting them. A result of this program is the formalizing of criteria for a better computer diode.

#### 198. AN ANALYSIS OF CRYSTAL DIODES IN THE MILLIVOLT REGION

W. B. WHALLEY, N. P. SALZ, AND  
C. MASUCCI  
(Sylvania Electric Products Inc.,  
Bayside, N. Y.)

Crystal diodes, when operated as detectors for signal inputs of the order of a few millivolts, present new problems regarding their exact behavior. Methods of rapidly testing the crystal performance in this region have been devised and the equipment re-

quired for the measurements has been designed and constructed.

A theoretical analysis will be presented of a type of crystal application which requires the detection of very small differences in large magnitude voltages. Data will be given for a number of types of crystal diodes tested for use in this application.

## Electron Tubes III—Cathode-Ray Tubes

Chairman, R. R. LAW

(Radio Corporation of America, Princeton, N. J.)

### 199. THE ANATOMY OF CONTRAST RANGE IN CATHODE-RAY TUBES

J. H. HAINES

(Allen B. DuMont Laboratories, Inc., Passaic, N. J.)

AND

R. E. MUELLER

(formerly Allen B. DuMont Laboratories, Inc., Passaic, N. J.)

In metallized cathode-ray tubes the contrast range is degraded principally by two effects; normal reflections and halation. The contrast is controlled by three variables: faceplate transmission, faceplate reflection, and optical contact of the phosphor to the faceplate.

Detail contrast is defined as the brightness ratio between a large illuminated field and a small unexcited area in this field. Measurements on two flying-spot scanner tubes, identical except for faceplate transmission, showed only 10 to 1 detail contrast for a clear faceplate, but 100 to 1 for a 66 per cent transmission faceplate.

It is shown the detail contrast is half that measured at edge of a uniform raster. Simple measurement techniques are outlined.

### 200. THE SELF-FOCUS TUBE

A. Y. BENTLEY, K. A. HOAGLAND, AND H. W. GROSSBOHLIN

(Allen B. DuMont Laboratories, Inc., Clifton, N. J.)

By making use of an electron lens of improved geometry, it has been possible to mass-produce television cathode-ray tubes in which focus is maintained without the necessity of external magnetic fields or focus voltage sources. The advantages of the new lens structure as compared to conventional electrostatic focus lenses are discussed. The performance characteristics of a typical Selfocus picture tube are described and compared to the widely used magnetic-focus prototype. It is shown that equivalent, and in some cases, superior performance is attained with the Selfocus tube.

### 201. A NEW HIGH-SPEED CATHODE-RAY TUBE

H. J. PEAKE AND R. W. ROCHELLE

(Naval Research Laboratory, Washington, D. C.)

A cathode-ray tube, DuMont Type K-1056, has been developed to fulfill the need for displaying transient waveforms which require spot velocities up to thousands of inches per microsecond. The development of the tube is discussed and the characteristics of the production model are given. A "figure

of merit" is introduced which allows evaluation of the performance of a cathode-ray tube in a transient display application.

### 202. THE DEFLECTRON—A NEW SYSTEM FOR ELECTROSTATIC DEFLECTION

KURT SCHLESINGER

(Motorola, Inc., Chicago, Ill.)

The conventional method of electrostatic deflection is limited to angles of less than 30° and to beams of low intensity, because of its inherent pattern and focus distortion and small aperture.

This paper presents a new approach to the problem of wide-angle electrostatic deflection. Deflector electrodes of a composite type have been developed, which yield bi-axial deflection simultaneously, i.e., with a common center of deflection. Two forms of these "deflectron" units are presented; one circular and one rectangular. The circular deflectron lends itself to radar and oscilloscope applications, while the rectangular deflectron was developed for picture tubes. "Deflectrons" are made of glass, using photographic methods. The lecture will describe the tubes, their associated circuits, and include a demonstration of a deflectron in operation.

### 203. FIELD PLOTTING AS A TOOL IN DEFLECTION YOKE DESIGN

E. SIEMINSKI

(Sylvania Electric Products, Inc., Bayside, N. Y.)

Deflection yoke design is predominantly empirical in practice. Mathematical analysis loses its utility because assumptions must be made in considering the many factors which affect a useful result. This paper describes a study of magnetic deflection field distributions, emphasizing their value in promoting a more precise design of deflection yokes. Field plots of windings in various configurations are compared for analysis. Measurement procedures are described and equipment, built for this investigation, is illustrated and treated in detail. The technique is particularly of value in that it helps to bridge the gap between the complexity of a theoretical approach and the inadequacy of an empirical solution.

## SYMPOSIUM

### What's New in Mobile Radio

(Organized by Professional Group on Vehicular Communications)

Chairman, AUSTIN BAILEY

(American Telephone and Telegraph Company, New York, N. Y.)

### 204. MOBILE RADIO PROBLEMS RESULTING FROM NEW TECHNIQUES

E. L. WHITE

(Federal Communications Commission, Washington, D. C.)

The development of equipment giving satisfactory performance on frequencies above 30 mc initiated a phenomenal growth in the mobile service. This growth has been further accelerated by the development of equipment for operation above 100 mc. As a result, in many services and in many fre-

quency bands the numbers of stations has increased to an extent that congestion is serious. Relief must be found. The development of mobile equipment for the bands above 400 mc offers the opportunity for the transfer of a considerable portion of the communications load from the lower frequencies. Developments of new circuits and components permitting closer spacing between channels will result in more economic use of the frequency bands available for mobile use. Better circuit discipline and more efficient operating procedures will permit the transmission of a greater volume of intelligence during available circuit time. The degree to which mobile radio can serve our economy depends to a great extent upon success in achieving maximum frequency utilization, and is a challenge to the designer, the manufacturer, and the user.

### 205. APPLICATION OF VOICE-FREQUENCY TONE SIGNALING TO MOBILE RADIO SYSTEMS

C. L. ROUALT

(General Electric Company, Syracuse, N. Y.)

Certain theoretical concepts relative to feedback-type selective amplifiers have been reduced to practice, resulting in two basic elements useful in a signalling system. These are a tone generator and a selective amplifier. The tone generator possesses excellent stability and the selective amplifier permits ready attainment of Q's of 200 in the voice frequency band 300–3,000 cycles per second. These basic elements have been employed in a number of signaling systems for signalling from a base station to individual or groups of mobile units and from the mobile units to the base station. The essentially electronic nature of these systems contributes to exceptional speed of operation and excellent reliability.

### 206. DISPATCHER'S WAYSIDE-TO-TRAIN RADIO CONTROL SYSTEM

S. D. BURTON

(Bendix Radio Division, Baltimore, Md.)

Control of the movement of trains over a railroad division and how direct radio communication between a dispatcher and train crews can greatly expedite train operation with safety will be considered. The original requirements set forth by the Northern Pacific Railroad for a complete dual-channel automatic train communication system and how these requirements were resolved engineering-wise to a series of unitized equipments which can be grouped to fulfill the system requirements of any railroad will be outlined. The paper will close with a step-by-step description of the operation of a typical system.

### 207. NEW DEVELOPMENTS IN ARMY MOBILE COMMUNICATION EQUIPMENT

J. H. DURRER

(Coles Signal Laboratory, Ft. Monmouth, N. J.)

As a result of an intensive post war development program by the Signal Corps Engineering Laboratories in conjunction with private industry, large scale production of an entirely new series of forward combat

area mobile and portable communication equipments has begun. The features of these new equipments, including ease of channel changing, crystal saving, flexibility, interchangeability, remote control, retransmission facilities, and selectivity and stability characteristics will be discussed.

## SYMPOSIUM

### Reliability of Military Electronic Equipment

(Organized by Professional Group on Quality Control)

*Chairman, J. R. STEEN*

(Sylvania Electric Products Inc.,  
New York, N. Y.)

#### 208. DISCUSSION OF THE COMPLEXITY AND UNRELIABILITY OF MILITARY EQUIPMENT AND THE NEED FOR SIMPLIFICATION AND INCREASED LIFE

A. S. BROWN

(Stanford Research Institute,  
Stanford, Calif.)

The paper is a discussion and criticism of the complexity, unreliability, and short life of military electronic equipment. It is a proposal to add to the usual military characteristics, requirements for maximum of simplicity, longevity, reliability, and usability

as a goal for engineers. Examples of World War II equipment, its maintenance and operation during that time, are given and its status during the subsequent years. Some suggestions are offered for maximum improvement in the future using transistors, ruggedized tubes, and other devices. Recommendations are made for streamlining research and development in the Armed Forces and urging of earlier co-operative decisions.

#### 209. MAINTENANCE MINIMIZATION IN LARGE ELECTRONIC SYSTEMS

W. D. McGUIGAN

(Stanford Research Institute,  
Stanford, Calif.)

Some of the effects of unitized packaging on reliability and economy in electronic systems are discussed. Examples are given both of circuit designs and panel layouts which tend to simplify the maintenance and recognition of performance. The factors governing the division of a system into packages and the design of a fault-location system are outlined. The paper concludes with an outline of some of the system factors requiring further investigation in the quest for reliability.

#### 210. THE RELIABILITY PROBLEMS IN MISSILE DEVELOPMENT

A. C. PACKARD AND R. WELLER

(U. S. Naval Air Missile Test Center,  
Point Mugu, Calif.)

The efforts to develop a satisfactory guided missile have forced us to operate in an environment which taxes the ingenuity of man and about which relatively little is known. Operating a new power plant in a newly designed vehicle at heretofore unattained speeds with a complex guidance and control system never before attempted has placed tremendous demands on equipment designers and technique developers.

#### 211. APPLICATION ENGINEERING FOR IMPROVED ELECTRONIC RELIABILITY IN GUIDED MISSILES

W. T. SUMERLIN

(Philco Corporation, Philadelphia, Pa.)

The means for transplanting standardized, accepted electronic equipment and systems from their customary environments into guided missiles merits special consideration in the realm of application engineering. Of most general interest, perhaps, is a review of such, tailored to fit the viewpoint of an electronic manufacturer who faces his first production of some typical guided missile. Indocrinating this manufacturer's organization is considered, and items such as circuit design, component selection, fabrication techniques, testing facilities, and supervision are discussed in the light of high reliability in the special environment applicable. Examples are given.

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S. S. Krinsky  
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G. D. O'Neill  
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Mrs. S. L. Bailey  
Mrs. I. S. Coggeshall  
Mrs. R. V. Gould  
Mrs. Roger McSweeney  
Mrs. Ogden Prestholdt  
Mrs. Carl Scholz  
Mrs. D. B. Sinclair

# Contributors to Proceedings of the I.R.E.

Fred Assadourian was born on April 13, 1915, in Panderma, Turkey. New York University conferred the B.S. degree on him in 1935, the M.S. in 1936, and the Ph.D. degree in mathematics in 1940.

From 1937 to 1942, Dr. Assadourian instructed in mathematics at New York University and, from 1942 to 1944, he was an associate professor of mathematics at Texas Technological College.

FRED ASSADOURIAN

Engaged as a research engineer at the Westinghouse Research Laboratories from 1944 to 1946, Dr. Assadourian worked on pulse transformers. Since 1946, he has been a development engineer at Federal Telecommunication Laboratories, where he is doing theoretical work in electronics and communication.

Dr. Assadourian is a member of the American Mathematical Society and of Phi Beta Kappa.



William S. Bachman was born on October 29, 1908, at Williamsport, Pennsylvania. He is a graduate of Tower Hill School in Wilmington, Delaware, and received a degree in electrical engineering from Cornell University in 1932.

In 1934, Mr. Bachman joined the Radio Receiver Engineering Department of the General Electric Company where he worked on loudspeakers, FM

and AM radio receivers, and phonograph combinations. In 1946 he joined Columbia Records, Inc., where he is currently Director of Engineering and Development.

Mr. Bachman received the Charles A. Coffin award for work on feedback amplifiers, and is also the designer of the G.E. Variable Reluctance Phonograph Reproducer. He contributed to the development of the Long Playing Microgroove record, and was responsible for getting it into commercial production.

Mr. Bachman is a member of Eta Kappa Nu and of Tau Beta Phi.



Gail E. Boggs was born in Chicago, Illinois on April 22, 1921. He attended the Illinois Institute of Technology in 1942, and was graduated from the George Washington University with the degree of B.E.E. in 1948. At present, he is enrolled

in the Graduate School of the University of Maryland.

From 1941 to 1942, Mr. Boggs was employed by the Belmont Radio Corporation of Chicago. He entered the Armed Forces in 1943, and was assigned to the Communications Laboratory of the Office of Strategic Services in 1944, serving as design engineer on military communications equipment until the end of 1945.

GAIL E. BOGGS

Since 1948, he has been employed by the National Bureau of Standards in the Experimental Ionospheric Research Section of CRPL in Washington, D. C. During this period, his work has involved the investigation of gain stability problems encountered in field intensity recording.



Edwin L. Chinnock was born in Brooklyn, New York on August 25, 1916. After attending Stevens Institute of Technology, he was employed by The Electrical Industries Manufacturing Co. In 1939 Mr. Chinnock joined the radio research department of the Bell Telephone Laboratories at Holmdel, N. J. He was called to active duty with the U. S. Navy in 1940, and was assigned to a



E. L. CHINNOCK

classified group which received a special unit citation for their work during the war.

After being discharged as a Chief Radioman in 1945, Mr. Chinnock returned to the radio research department of the Bell Telephone Laboratories at Holmdel, N. J., where he has done research on microwave relay systems, the close-spaced triode, and the measurement of noise figures.



Frank G. Cole (S'48-A'51) was born in Newton, Mass. on April 30, 1927. He received the B.S. and M.S. degrees in electrical engineering from the Massachusetts Institute of Technology, the latter in 1950. He attended the co-operative course in conjunction with the Philco Corporation.



FRANK G. COLE

Mr. Cole was a Radio Technician in the Navy from 1945 to 1946. He has worked for the General Electric Receiver

Department from 1950 to the present on TV sweep systems engineering, and primarily on the development of the wattmeter. His present assignment in the Government Section is with Airborne radar.

Mr. Cole is a member of Eta Kappa Nu.



For a photograph and biography of J. M. DIAMOND, see page 438 of the April, 1951, issue of the PROCEEDINGS OF THE I.R.E.



J. J. Ebers (S'46-A'48) was born in Grand Rapids, Mich., on November 25, 1921. He received the B.S. degree from



J. J. EBERS

Antioch College in 1946, his education having been interrupted by three years' service in the U. S. Army. He obtained the M.S. degree in electrical engineering from Ohio State University in 1947, and the Ph.D. in 1950. Since 1947 he has been an instructor in the electrical engineering department of this university, as well as a research associate for The Ohio State University Research Foundation. Recently he has received an appointment as assistant professor.

Dr. Ebers is a member of Eta Kappa Nu, Sigma Xi, and the American Physical Society.



Donald E. Garrett (S'48-A'49) was born on April 24, 1922, in McCloud, Okla. He attended the University of Kansas from 1939 to 1941, and received the B.S. degree in electrical engineering from the University of Washington in 1948 after two years, spent there. In 1950, he received the S.M. degree in electrical engineering from the Massachusetts Institute of Technology.



D. E. GARRETT

From 1941 to 1944, Mr. Garrett worked for the Boeing Airplane Company in Seattle, Wash., on control, armament, and miscellaneous electrical problems on the B-17 Flying Fortress, the C-97 Strato Freighter, the B-50, and the Stratocruiser. After two years (1944 to 1946) as an electronic technician in the Navy, he rejoined the Boeing Company, and from 1948 until 1950, he worked on guided missiles for the Research Laboratory of Electronics at M.I.T.

Since 1950, Mr. Garrett has worked on TV sweep circuit, high voltage, and meas-

# Contributors to Proceedings of the I.R.E.

urement problems for the General Electric Receiver Department. His present assignment is color television.

Mr. Garrett is a member of Sigma Xi and RESA.



Raymond F. Guy (A'25-M'31-F'39) was born in Hartford, Conn., on July 4, 1899. In 1916 he entered radio professionally with the Marconi Wireless Telegraph Company, and during World War I he served overseas with the Signal Corps of the United States Army. Upon being discharged, he entered Pratt Institute, from which he graduated with an electrical engineering degree in 1921.



RAYMOND F. GUY

In the same year Mr. Guy was engaged as a broadcast engineer for WJZ. In 1924 he became a member of the engineering staff of the RCA Research Laboratories, where he supervised engineering, development, and construction of standard and short-wave broadcasting apparatus, stations, and systems, and participated in RCA's earliest television development.

In 1929 Mr. Guy transferred to the National Broadcasting Company to direct its frequency allocations engineering, and the planning, design, and construction of all NBC transmitting facilities. He is now Manager of Radio and Allocations Engineering for NBC.

Mr. Guy has been active in Institute affairs for over twenty years: he was a Director starting in 1943, Treasurer in 1947, and President in 1950, and is currently Senior Past President and Membership Relations Co-ordinator. He is a charter member of the Radio Pioneers, a life member of the Veterans' Wireless Operator's Association, a Fellow of the Radio Club of America, a member of the Radio Executives Club, and an associate of the Association of Federal Communications Engineers.



Arthur A. Hauser, Jr. (M'48) was born in Dayton, Ohio, on January 28, 1920. He received his B.S. degree from the Massachusetts Institute of Technology in 1942,



A. A. HAUSER, JR.

and his M.S. degree from New York University in 1950. From 1941 to 1942, Mr. Hauser was an assistant in the Physics Department at the Massachusetts Institute of Technology. He joined the Sperry Gyroscope Company in 1942 and remained

with them until 1946, during which period he was successively an assistant project engineer and project engineer. In 1946 he became an instructor in the Department of Mathematics at the Rensselaer Polytechnic Institute. In 1947 Mr. Hauser returned to Sperry, where he served successively as project engineer, senior project engineer, and research engineer.

At present, Mr. Hauser is engineering section head for Electronics at the Sperry Gyroscope Company.



Robert S. Hoff (A'46-M'50) was born in Delavan, Ill., on March 12, 1920. He received the B.S. degree in electrical engineering from the Texas A. and M. College in 1941 and the M.S. degree in engineering from the University of Florida in 1950.



ROBERT S. HOFF

From 1941 to 1946 Mr. Hoff served as an officer with the Signal Corps, in which capacity he was engaged in staff work pertaining to radar installation and maintenance and to radio intelligence training, organization, and equipment development guidance. In his last year of service as Organization and Training Officer, in the grade of Major, of an agency of the Army Communications Service, Mr. Hoff was awarded the Legion of Merit.

After leaving the Army, Mr. Hoff joined the Engineering and Industrial Experiment Station, University of Florida, as leader of an Air Force-sponsored low-frequency atmospheric noise and wave-propagation project. He is a member of Commission IV, Terrestrial Noise, of the American Section of URSI, and has presented papers at technical meetings of that organization.

Mr. Hoff joined the Ordnance Development Division of the National Bureau of Standards in 1950, and is presently an engineer in charge of a development project.



C. W. Horton was born on September 23, 1915, at Clerryvale, Kan. He received the B.A. degree with honors in physics in 1935, and the M.A. degree in 1936, both from The Rice Institute, in Houston, Tex. In 1945 he was awarded the Ph.D. degree from the University of Texas.



C. W. HORTON

Dr. Horton was a research associate at the Underwater Sound Laboratory, Harvard University, from 1943 to 1945.

For this work he received a Development Award from the U. S. Navy Bureau of Ordnance, and a Certificate of Appreciation from the Office of Scientific Research and Development.

Since 1945 he has been a research physicist at the Defence Research Laboratory and an associate professor of physics at the University of Texas, Austin, Tex. He is a member of the American Physical Society, the American Geophysical Union, and the Society of Exploration Geophysicists.



Craig C. Johnson was born in San Marcos, Texas, on February 27, 1924. He entered the University of Texas in 1941 and graduated in 1948 with a B.S. degree in mechanical engineering, having spent three years, 1943 through 1945, as an Air Force pilot.



CRAIG C. JOHNSON

After graduation, Mr. Johnson joined the Defense Research Laboratory at the University of Texas as a research engineer engaged in guided missile work for the United States Navy. Since June, 1951 he has been employed as a research engineer at the North American Aerophysics Laboratory in Downey, Calif.

While at college Mr. Johnson was a student member of the American Society of Mechanical Engineers. He is a member of Phi Eta Sigma, Pi Tau Sigma, and Tau Beta Pi. In 1947 he was awarded a Westinghouse Achievement Scholarship.



Raymond C. Johnson (A'46-M'49) was born in Galveston, Texas on September 29, 1922, and was educated at Texas A. and M.



R. C. JOHNSON

College, where he received the B.S. degree in electrical engineering in 1946, and at the University of Florida, where he took the M.S. degree in electrical engineering in 1949. He completed the Army training course at the Long Lines Inside Plant and the Army electronics training course at Harvard and the Massachusetts Institute of Technology.

As an assistant research professor at the University of Florida, Mr. Johnson is currently devoting his time to classified research in electronics for the Federal government. Prior to 1946, when he joined the staff of the College of Engineering, he had two years of Army radar experience with the Signal Corps Engineering Laboratories,

# Contributors to Proceedings of the I.R.E.

where he worked on new radar equipment. This included one year in the European and Pacific war theaters.

Mr. Johnson is a member of the American Institute of Electrical Engineers.



Hugh LeCaine was born in Port Arthur, Ontario, Canada, on May 27, 1914. He received the B.Sc. degree in engineering physics from Queen's University, Kingston, Ontario, in 1938, and the M.Sc. degree in physics from the same University in 1939. The following year was spent in research work at Queen's University on a National Research Council Studentship. In 1940 he joined the staff of the National Research Council of Canada, where he now holds the position of assistant research officer.

From 1948 to date, Mr. LeCaine has been on leave-of-absence, and has been pursuing graduate studies at the University of Birmingham, England, on a National Research Council Fellowship.



Chester M. McKinney (S'43-A'45-M'49) was born on January 29, 1920, in Cooper, Texas. He received the B.S. degree in physics from the East Texas State Teachers College in 1941, followed by the M.A. in 1947 and the Ph.D. in 1950 in physics from the University of Texas. Mr. McKinney served as a radar officer in the Air Force from 1942 to 1946. He was a research physicist at Defense Research Laboratory of The University of Texas from 1946 to 1950, and an assistant professor of physics at Texas Technological College from September, 1951, to the present.

Mr. McKinney was recalled to active duty in the Air Force, in June, 1951.



Horst A. Poehler (S'41-A'44) was born in Gera, Germany on October 9, 1917. He received the B.E.E. degree from the Polytechnic Institute of Brooklyn in 1939, pursued one year of graduate study at the Moore School of the University of



HORST A. POEHLER

he worked on vacuum tube problems. From 1944 through 1946, he held the position of project engineer at the International Electronics Laboratories, New York, and was concerned with instrumentation and control problems in industry. In 1946 he was awarded a graduate fellowship and returned to Columbia University to resume graduate studies.

Since 1948 Dr. Poehler has been a staff member with the General Precision Laboratory, Inc. at Pleasantville, New York. His work here is in the field of electro-mechanical measuring and computing circuits.

Dr. Poehler is a member of the American Institute of Electrical Engineers, Eta Kappa Nu, Pi Mu Epsilon, and Tau Beta Pi.



Henry J. Riblet (A'45) was born on July 21, 1913 at Calgary, Canada. He received the B.S. degree in 1935 and the Ph.D. degree in 1939 from Yale University.

From 1939 to 1942, Dr. Riblet taught mathematics, first as instructor at Adelphi College, and later as assistant professor at Hofstra College. From 1942 to 1945 he was at the Radiation Laboratory, where he was

in charge of one of the three design sections of the antenna group. From 1945 to 1949 he was in charge of the antenna and rf groups at the Submarine Signal Company. He is now employed by the Microwave Development Laboratories.



Walter J. Surtees (S'42-A'45-M'48) was born in Ottawa, Ontario, Canada, on January 1, 1922. He received the B.Sc. degree in Electrical Engineering in 1943 from Queen's University, followed by the M.A.Sc. degree in electrical engineering in 1947, from the University of Toronto.

From 1943 to 1946 Mr. Surtees served as signals officer with the Royal Canadian Air Force and from 1947 to

Pennsylvania, 1939-1940, received the M.A. degree in Pure Science from Columbia University in 1942, and received the Ph.D. degree from Columbia in 1948.

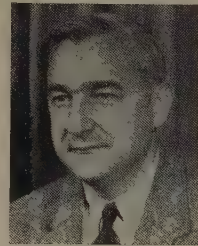
From 1942 to 1944 he was associated with the Westinghouse Electric Corporation, Bloomfield, New Jersey, where



WALTER J. SURTEES

he worked on vacuum tube problems. From 1944 through 1946, he held the position of project engineer at the International Electronics Laboratories, New York, and was concerned with instrumentation and control problems in industry. In 1946 he was awarded a graduate fellowship and returned to Columbia University to resume graduate studies.

Richard Theile was born in Halle, Germany, on March 23, 1913. He attended the Realgymnasium and University in Marburg and the Technische Hochschule in Berlin, and received the degree of Ph.D. in 1938 at the University of Marburg. He joined the Telefunken Company in 1936. Since that time he has been engaged in research and the development of television pick-up devices, camera tubes, and photo-multipliers, as well as other projects important to this field. From 1946 Dr. Theile was a lecturer in electronics at the University of Marburg, and he is at present engaged in television research at the laboratories of Pye Limited, in Cambridge, England.

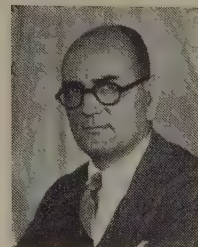


RICHARD THEILE

From 1939 to 1942, Dr. Riblet taught mathematics, first as instructor at Adelphi College, and later as assistant professor at Hofstra College. From 1942 to 1945 he was at the Radiation Laboratory, where he was



Frederick H. Townsend (SM-'49) was born in London, England on September 26, 1911. He received his technical education at the Northampton Polytechnic Institute, London. In 1930 he joined the Valve Department of Standard Telephones and Cables Ltd., and in 1931 went to A. C. Cossor Ltd., as an assistant in their Research Department, where he remained until 1938. From 1938 to 1946 he was second-in-charge of the Vacuum Laboratory of Pye Ltd., in Cambridge, England. In 1946 he became Chief Vacuum Engineer and Manager of Cathodeon Ltd., the vacuum tube subsidiary of the Pye organization.



F. H. TOWNSEND

Mr. Townsend is also an Associate Member of the British organization, the Institution of Electrical Engineers, and is currently Chairman of the Cambridge Radio Group of the Institution.

Mr. Townsend is also an Associate Member of the British organization, the Institution of Electrical Engineers, and is currently Chairman of the Cambridge Radio Group of the Institution.

# Institute News and Radio Notes

## TECHNICAL COMMITTEE NOTES

The Standards Committee will hold a meeting during the 1952 IRE National Convention on Tuesday, March 4, at 8:00 a.m.

The Executive Committee, at its meeting on December 4, approved the change of names of the Committee on Modulation Systems to that of the Committee on Information Theory and Modulation Systems and the Committee on Electron Tubes and Solid-State Devices to that of the Committee on Electron Devices. At this meeting the appointment of A. G. Jensen as Chairman of the new United States Committee (of CCIR), to handle questions involved in the work assigned to Study Group XIV (Vocabulary) of the Committee on International Radio Consultative, was confirmed.

The Standards Committee convened on December 13, under the Chairmanship of A. G. Jensen. J. W. Horton's paper, "Fundamental Considerations Regarding the Use of Relative Magnitudes," was approved by the Committee and will appear in the PROCEEDINGS. E. A. Laport's idea for an Electronics Encyclopedia was endorsed by the Committee. The proposed "Standards on Electron Tubes: Methods of Testing Gas-Filled Radiation Counter Tubes," together with the "Gas-Filled Counter-Tube Definitions," which were approved at this meeting by the Standards Committee on November 8, will be sent back to the sponsoring Committee (Electron Devices) for their approval. A new ruling was adopted by the Standards Committee that, after being approved, all definitions and methods of testing would be sent back to the sponsoring Committee for its approval. If the Committee does not agree with the changes made by the Standards Committee, they may so advise the Committee. Revision of the Standards Committee Manual was also discussed.

A meeting of the Committee on Antennas and Waveguides was held on November 13, under the Chairmanship of A. G. Fox. A major part of the meeting was devoted to a discussion of "Q" definitions, both "of a medium" and "of a waveguide." Notes on the "Q" concept, as written by Mr. Fox, were used as starting points.

The Facsimile Committee convened on November 2, under the Chairmanship of R. J. Wise. Mr. Wise proposed the establishment of a Subcommittee to develop and present a suitable test pattern, and asked for ideas and suggestions which might be helpful to this group. It was suggested that means for measuring definitions be given particular emphasis. The subject was discussed at some length, and a number of suggestions were made as to methods of supplementing the test pattern or to alternatives which might provide a better indication of definitions.

The Committee on Navigation Aids convened on November 19, under the Chairmanship of P. C. Sandretto. General Sandretto reported, to the Committee Members present, on the action taken at the November 8 meeting of the Standards Committee, rela-

tive to the controversial term "Fruit Pulse." He reported that the Definition which the Committee on Navigation Aids has proposed had been accepted by the Standards Committee. The Committee then turned its attention to a review of navigation terms.

The Committee on Measurements and Instrumentation convened on November 16, under the Chairmanship of F. J. Gaffney. Three topics for standards work by the Subcommittee on Video-Frequency Measurements were proposed: (a) measurement of impedance at video frequencies, (b) video measurements employing transient techniques, and (c) measurements of time for video signals. It was requested that these proposals be reviewed and comments sent to the Chairman of the Subcommittee. Attention was called to the meeting on Electrical Insulation, which was held at the National Bureau of Standards on October 29-31, and sponsored by the National Research Council. A brief summary will be contained in the Annual Review. The Chairman reported that most of the Annual Review reports were now in, and the remaining ones have been promised shortly. A new method of measurement of the dielectric properties of gases, developed by the Bureau of Standards was reported on by J. L. Dalke.

The Committee on Wave Propagation convened on December 11, under the Chairmanship of H. G. Booker. The proposed, "Standards on Wave Propagation: Standards of Measuring," drawn up by Subcommittee 24.1, was considered, and approved. The document, "Tropospheric Propagation: A Selected Guide to the Literature," was also considered, and approved. Discussion was given to a document entitled, "Definitions of Terms Relating to Propagation in the Troposphere," which was adopted unanimously at the Plenary Session of the CCIR on July 3, 1951. The feeling of the Committee was that, while there was no violent reaction to any of the definitions concerned, nevertheless the document could not be considered as an improvement upon the IRE Tropospheric Definitions, published in the November, 1950, issue of the PROCEEDINGS. The Committee felt that the proper course was to consider the CCIR definitions in connection with the next revision of the IRE definitions and that no special action should be taken at the present time. It was reported that the Radio Astronomy Definitions, which were approved at the last meeting of the Committee, will be published in the near future.

At the December 7 meeting of the United States National Committee of the International Electrotechnical Commission, W. R. G. Baker, representing the RTMA, and F. B. Llewellyn, representing the IRE, were re-elected to their respective posts.

At the meeting of the Committee on Electrical Standards, of the American Standards Association, held on December 7, C. R. Harte and W. R. G. Baker were re-appointed Chairman and Vice-Chairman, respectively. Dr. Baker is the new Vice-Chairman of the Communications and Electronics Division of the Committee on Electrical Standards, and

Harry Brown has relieved Sidney Withington as Vice-Chairman of the Power Division of the ESC. W. R. G. Baker and L. G. Cumming were appointed as members of the Executive Committee. Other members of the Executive Committee will be C. R. Harte, P. H. Chase, M. Brandon, J. J. Pilliod, R. C. Sogge, H. Brown, and Colonel Ice.

## BRITISH RADIO SHOW SLATED

The ninth annual private exhibition of British components, valves, and test gear for the radio, electronic, and telecommunication industries is scheduled for April 7-9, 1952, at the Grosvenor House, London, Eng.

An exhibition is being promoted to show the advances in design and development of British instruments. A warm welcome is extended to those interested in this country.

## Calendar of COMING EVENTS

1952 IRE National Convention, Waldorf-Astoria Hotel and Grand Central Palace, New York, N. Y., March 3-6

IRE Connecticut Valley Section, Electronics Industry Day, Storrs, Conn., April 5

Annual British Radio Component Show, Grosvenor House, London, England, April 7-9

Radio and Television Show, Manchester, England, April 23-May 3

IRE Cincinnati Section, Spring Technical Conference, Cincinnati Engineering Societies Building, Cincinnati, Ohio, April 19

URSI-IRE Spring Meeting, National Bureau of Standards, Washington, D. C., April 21-24

IEE Television Convention, London, England, April 28-May 3

IRE-AIEE-RTMA Symposium on Progress in Quality Electronic Components, Washington, D. C., May 5-7

IRE New England Radio Engineering Meeting, Copley Plaza Hotel, Boston, Mass., May 10

IRE National Conference on Airborne Electronics, Hotel Biltmore, Dayton, Ohio, May 12-14

4th Southwestern IRE Conference and Radio Engineering Show, Rice Hotel, Houston, Tex., May 16-17

Radio Parts and Electronic Equipment Show, Conrad Hilton Hotel, Chicago, Ill., May 19-22

1952 IRE Western Convention, Municipal Auditorium, Long Beach, Calif., August 27-29

National Electronics Conference, Chicago, Ill., September 29-October 1  
IRE-RTMA Radio Fall Meeting, Syracuse, N. Y., October 27-29

# Institute News and Radio Notes

## PROFESSIONAL GROUP NOTES

An invitation has been issued to all IRE Professional Groups to attend the 1952 Centennial of Engineering, to be held in Chicago, on September 3-13, 1952. All Groups interested in participating in this event should advise the IRE Headquarters as soon as possible.

The IRE Professional Groups Administrative Committees who have registered with Headquarters to hold meetings at the 1952 IRE National Convention are scheduled as follows: **Airborne Electronics**, Thursday, March 6, Moderne Room, Belmont Plaza Hotel; **Antennas and Propagation**, Wednesday, March 5, Jade Room, Waldorf Astoria Hotel; **Broadcast Transmission Systems**, Wednesday, March 5, Ballroom, Waldorf Astoria Hotel; **Circuit Theory**, Monday, March 3, Astor Gallery, Waldorf Astoria Hotel; **Electronic Computers**, Wednesday, March 5, Blue Room, Grand Central Palace; **Engineering Management**, Monday, March 3, Grand Ballroom, Waldorf Astoria Hotel; **Information Theory**, Monday, March 3, Jade Room, Waldorf Astoria Hotel; **Vehicular Communications**, Thursday, March 6, Maroon Room, Grand Central Palace. According to a policy set up by the IRE Headquarters, these meetings will be held on the mornings of the Convention days, to be adjourned no later than 9:30 a.m.

The IRE Professional Group on Airborne Electronics will hold a luncheon during the 1952 IRE National Convention, on March 5, in the Baroque Room of the Belmont Plaza Hotel, at 12 noon.

The IRE Committee on Professional Groups will hold a meeting during the 1952 IRE National Convention on the morning of Tuesday, March 4, in the Grand Ballroom of the Waldorf Astoria Hotel.

W. H. Doherty, Chairman of the IRE Technical Program Committee of the 1952 IRE National Convention, has announced that all IRE Professional Groups except Nuclear Science will be represented at the Convention by technical sessions or symposia.

The dates of the IRE National Conference on Airborne Electronics, to be held in Dayton and sponsored by the IRE Professional Group on Airborne Electronics, have been changed to May 12-14, 1952, in order to avoid conflict with the Symposium on Components to be held in Washington, D. C.

Dr. George Sinclair, Chairman of the IRE Professional Group on Antennas and Propagation, has announced the election of A. H. Waynick as Vice Chairman of the Group for the current year. The material for the first issue of this Groups publication "Transactions" will be available for distribution shortly.

The IRE Professional Group on Audio, under the Chairmanship of B. B. Bauer, has announced that beginning with the January, 1952, issue of the AUDIO NEWSLETTER, the last page of the publication will be devoted to institutional advertisements by various companies in the industry. The price for a listing in 6 issues will be \$25. The Group has

recently made available for distribution to the membership, "Transactions of the Professional Group on Audio," comprising four papers as follows: "Horn Loaded Loudspeakers," by D. J. Plach and P. B. Williams; "Wear of Phonograph Needles," by B. B. Bauer; "A Selective Automatic Phonograph Mechanism," by J. C. Kiefer and A. G. Bodoh; and, "An Electronic Music Box," by E. L. Kent.

Under the Chairmanship of D. D. Israel, the IRE Professional Group on Broadcast and Television Receivers, announced the distribution to the entire membership of an assessment notice levied at a cost of \$2.00 per member, to defray expenses incurred through publication of technical papers of interest to its members. Members were requested to return payment forms with check to the IRE Headquarters by January 15, 1952.

The petition for the formation of the IRE Professional Group on Electronic Computers has been approved by the IRE Executive Committee. Acting-Chairman M. M. Astrahan has announced the appointment of the Administrative Committee Members of the Group as follows: one-year terms—W. F. Gunning, H. H. Sarkissian, E. G. Andrews, and J. H. Pomerene; two-year terms—G. W. Downs, H. D. Huskey, J. H. Howard, and M. M. Astrahan; three-year terms—W. D. Caldwell, T. A. Rogers, J. R. Weiner, and S. N. Alexander.

IRE Headquarters has announced the approval of the IRE Professional Group on Electron Devices Constitution, by the IRE Executive Committee, on December 4, 1951. The Acting Chairman of the Group is G. D. O'Neill of Sylvania Electric Products Company, Bayside, N. Y.



## IEE CONVENTION PLANS ADVANCE

Further plans have been announced for the convention on "The British Contribution to Television," sponsored by the Institution of Electrical Engineers. The convention, to which all IRE members have been invited, is scheduled for April 28 to May 3, 1952, London, England.

The number of technical papers on which discussion will take place will be between 60 and 80, many of which have already been submitted. Technical sessions covering all aspects of television from the program production to the viewer will be supported by interesting demonstrations of television equipment, including large-screen projection television and, possibly, an early Baird 30-line equipment which is at present being re-assembled.

During the convention, visits of inspection will include the BBC television studios and the latest television transmitters, the post office research station, and commercial organizations manufacturing television equipment of the London-Birmingham co-axial cable link and others.

Information concerning procurement of registration forms and additional program plans may be found on page 1467, of the November, 1951, issue of the PROCEEDINGS.

## NOTICE! MEMBERS

The IRE Professional Group on Electronic Computers announces that Members who have not previously indicated interest can obtain application forms from the Membership Chairman, J. R. Weiner, Eckert-Mauchly Computer Corporation, 3747 Ridge Avenue, Philadelphia 32, Pa. The Group will sponsor a Symposium on Magnetic Core Memory Devices at the 1952 IRE National Convention. Information about the Group will be available at the Professional Group desk during the Convention.

## URSI/IRE SPRING MEETING SCHEDULED

A meeting of the USA National Committee of the International Scientific Radio Union (URSI), and the IRE Professional Group on Antennas and Propagation will be held at the National Bureau of Standards, Washington, D. C., on April 21-24, 1952.

Sessions will be held concerning the following topics: radio measurement methods and standards, tropospheric radio propagation, ionospheric radio propagation, terrestrial radio noise, radio astronomy, antennas and waveguides, radio waves and circuits (including general theory), and electronics (tubes and semiconductors).

A preliminary program and advance registration forms will be available after March 10, 1952. These and further information concerning the meetings may be obtained from A. H. Waynick, Secretary, U.S.A. National Committee of URSI, Pennsylvania State College, State College, Pa.



## OVER 900 ATTENDANCE AT IRE-AIEE CONFERENCE

More than 900 engineers, scientists, and mathematicians attended the joint IRE-AIEE Computer Conference held in Philadelphia, December 10-12, 1951. The meeting afforded the first opportunity for manufacturers and users of large-scale digital computing equipment to exchange information on results obtained from completed machines. Ten computers were described in some detail including two machines located in Great Britain, with papers and discussions presented by the various representatives and authorities of the machines.

The papers and discussions which were contributed to the oral presentations will be collected and bound in a Proceedings which should be available soon. These written papers are more complete than the oral presentations. These Proceedings will be sold for \$3.50 a copy and may be obtained from the AIEE or IRE Headquarters.

Information on the program schedule and machines discussed at the conference can be found on page 1466, in the November, 1951, issue of the PROCEEDINGS.

# IRE People

Patrick E. Sullivan (M'48) has been appointed assistant manager of the Buffalo Tube Works of the General Electric Company. Mr. Sullivan has been works engineer at the Buffalo GE plant since 1947.



P. E. SULLIVAN

A native of Detroit, Mr. Sullivan graduated from the University of Detroit in 1942, with a B.S. degree in electrical engineering. He joined the General Electric Company in 1942 as a trainee in the test engineering program at Bridgeport, and then transferred to the Buffalo plant as a quality engineer. He was appointed assistant works engineer in 1946, and became a works engineer in 1947.

He is a member of the American Society for Quality Control.

Raymond Collins (A'40) who was the assistant general manager of radio stations WFAA and WFAA-TV, Dallas, Texas, died recently at his home after an illness of several months.

Mr. Collins was born in 1907, and studied electrical engineering at the Southern Methodist University. He joined WFAA in 1928, becoming the technical supervisor in 1935. During World War II, he participated in radar development and research at the Radio Research Laboratory at Harvard University. In 1944, he was one of 16 engineers chosen to perfect countermeasure radar equipment at the request of General Dwight D. Eisenhower. This work consisted of jamming the German radar network along the French coast before the invasion by the allied forces.

After the war, Mr. Collins returned to WFAA where he was in charge of technical operations until his death. Mr. Collins was a charter member of the Dallas IRE Section.

Carl E. Scholz (M'26-SM'43) has been elected vice president and chief engineer of the American Cable and Radio Corporation. Prior to this appointment Mr. Scholz has served in the same capacity for three operating subsidiaries of AC&R; the Mackay Radio and Telegraph Company, the Commercial Cable Company, and All America Cables and Radio, Incorporated.

Mr. Scholz has been associated with The International Telephone and Telegraph Corporation, an affiliate of AC&R, since

1917, when he joined the Federal Telegraph Company as an engineer. With the exception of a few years in South America, Mr. Scholz has spent most of his career at IT&T headquarters in New York, working on engineering and design problems for the various subsidiary companies. Mr. Scholz is also a member of the American Institute of Electrical Engineers.



Ross Gunn (A'35-SM'47-F'49) has received the 1951 Air Safety Award from the Flight Safety Foundation, Incorporated.



ROSS GUNN

Dr. Gunn, who is the Director of Physical Research, United States Weather Bureau, Washington, D. C., has specialized in the invention and development of new electrical instruments and electronic devices, including early radio control apparatus for airborne missiles. In 1945, he was cited by the Secretary of the Navy for Distinguished Civilian Service, in connection with the development of the atomic bomb.

Dr. Gunn was born in Cleveland, Ohio, in 1897. He received the degrees of B.S.E.E., and M.S., in physics from the University of Michigan in 1920 and 1921, respectively, and the Ph.D. degree from Yale in 1926. He was a wireless operator on the Great Lakes during 1915-1917, and was a special instructor in radio courses at the University of Michigan in 1918. From 1920 to 1922, he was an instructor in physics at the University of Michigan, and then became a radio research engineer in the U. S. Air Service, in 1922-1923. As an instructor in physics at Yale University in 1923 to 1927, he was put in charge of the high-frequency laboratory during 1926-1927.

In 1927 he joined the Naval Research Laboratory and became their chief physicist where he worked as the superintendent of the mechanics and electricity division, superintendent of the aircraft electrical research division, and technical director of the Army-Navy Precipitation-Static Project.

Dr. Gunn was presented the IRE Fellow Award in 1949, for his, "long service and many technical contributions in the radio and electronics fields." He is a fellow of the American Physical Society, and a member of the National Academy of Sciences.

Ralph R. Shields (M'50), formerly engineer for Sylvania test equipment merchandising, has been appointed merchandising supervisor for the television picture tube division of Sylvania Electric Products, Incorporated.



RALPH R. SHIELDS

A native of Pennsylvania, Mr. Shields received his engineering degree in 1938. During World War II, he served as administrative engineer of the Special Studies Branch, Signal Corps Engineering Laboratories, where he supervised research and development projects which eliminated radio interference from army vehicles.

Mr. Shields has authored many engineering and business paper articles on the technical and economic aspects of television servicing and servicing instruments.



Allen D. Cardwell (A'14-VA'39) inventor and founder of an electrical instrument manufacturing concern, died recently at the Nassau Hospital Mineola, L. I., N. Y. He was 63 years of age.

Mr. Cardwell, who retired in 1945, received early recognition as an inventor and designer in the printing telegraph field and for inventing a device to speed stock market tickers. A pioneer in the guided-missile field, he devised, in 1924, a system for such missiles that met the acceptance test of the British Government.

A holder of many patents in electronics, he was credited with having invented the first low-loss condenser to be manufactured in quantity. He was co-inventor with Ralph Batcher of an automatic calibration system used during World War II, for the calibration of high-frequency meters. He received a citation from the government for his work.

In retirement, Mr. Cardwell had been working on pilot models of physical therapy equipment to be used in the rehabilitation of disabled veterans. Mr. Cardwell was a native of Rochester, N. Y.

William Fingerle, Jr., (S'35-A'38-SM'47) has recently joined the Budelman Radio Corporation. In his new position he will be engaged in carrying out development contracts in the FM communications and multi-channel relay fields.

Mr. Fingerle was born on April 9, 1914, in New York, N. Y. He studied electrical engineering at the Massachusetts Institute of Technology where he received the B.S. degree in 1936. He then joined the Duro-Test Lamp Company as assistant chief engineer. In 1937 he became associated with the Link Radio Corporation where he served in a capacity as head of the department of development, design, and manufacture of high power FM, emergency, and television services, and as chief engineer.

Mr. Fingerle was also active in the development and application of military radio equipment during World War II.



William E. Osborne (A'41) has been elected President and General Manager of Resdel Engineering Company of Los Angeles.

He was previously Director of Electronics at the Hycon Manufacturing Company of Pasadena, California, for several years, where he organized the Electronics Division.



W. E. OSBORNE

Mr. Osborne was engaged in electronic and radar work after receiving the E.E. degree from Queen's College, Melbourne University, Australia, in 1925. Now a United States citizen, he served with both the British and Australian Forces during the war, as head of the Radiophysics Branch of the Australian Army, and as radar liaison officer to the United States and British Governments.

In 1945-1947, he was associated with

Gillfillan Brothers, Incorporated, of Los Angeles, as Principal Radar Design Engineer. Mr. Osborne holds a number of patents in the television, radar (GCA), infrared, and nucleonics fields.



J. P. Coughlin (S'43-A'46) has been appointed as manager of aircraft and electronic transformer sales of the General Electric Company. Mr. Coughlin has been with General Electric since 1941, when he was graduated from Pratt Institute with a degree in electrical engineering. Following service on the test course and as a design engineer for distribution transformers, he transferred to the specialty transformer division. He later became the assistant manager of this division, a position he held until his recent appointment.



## Books

### Les Tubes Electroniques a Commande par Modulation de Vitesse by R. Warnecke and P. Guenard

Published (1951) by Gauthier-Villars, 55 Quai des Grands Augustins, Paris, France. 792 pages, +22 pages +2-page errata. 476 figures.

R. Warnecke is the technical director of the electronics department, and P. Guenard is chief of the laboratory, Center of Technical Research, Campagne Generale de Telegraphie Sans Fil, Paris, France.

The scope of this book is adequately described in the authors' own foreword. They state that they have attempted to review all theoretical and technical literature on velocity modulation tubes that was available to them. As they both belong to the Laboratories of the Compagnie Generale de TSF, they have naturally based their work primarily on what has been accomplished there in this field, but they have also carefully studied a great number of other published or still unpublished material, with a particular mention of W. W. Hansen's and E. Feenberg's unpublished notes which have been graciously communicated to them. The bibliography included in the book contains 385 items carefully chosen to cover all important aspects of the problem.

The authors are careful to indicate that no complete deductive theory of any of the tubes will be found in their book. In fact, they claim that no such theory can be made, as restrictive assumptions have to be introduced to deal with practical cases and various facets of the problems involved in order to arrive at results applicable to actual structures. The approximations utilized are, however, very clearly mentioned

everywhere and the book undoubtedly constitutes a basic exposition of all principles underlying the design of this type of uhf and vhf tubes which remains of great importance in microwave techniques, and to the development of which the authors have themselves contributed considerably. It will be recalled that Dr. Warnecke was given an IRE Fellow Award in 1950 for his engineering and research contributions to vacuum-tube theory and design in France. Dr. Guenard is also a well known French expert in the field and both have filed a number of patent applications and published extensively.

The book is divided into seven parts. The first deals with the fundamentals of electronic behavior in velocity modulated tubes treating such questions as bunching and debunching of electrons, and influence of transit time in the interaction processes between fields and electrons. The second covers the essential facts about cavity resonators and the influence of shape and gaps on their properties. In the third part are gathered the basic theoretical explanations of the various types, such as two and three cavity amplifiers, frequency multipliers, reflex klystrons, and velocity modulated oscillators. The fourth part describes a number of structures and gives very useful data on the important components, as well as details on the less conventional devices such as coaxial line oscillators and various others due to Heil, Ludi, Hahn and Metcalf, and Coeterier. The fifth part comes back on theoretical considerations, incorporating refinements

and additional information with a view to approach correct design more closely. Here are found interesting chapters on how beams are focused, the way electrons behave in nonuniform fields, the influence of secondaries, space charge, electronic hysteresis, and relativity theory. Noise level and scaling problems are also discussed, together with the authors' method of designing a tube for specified characteristics together with specific examples. The sixth part is devoted to problems which arise in connection with circuitry associated with the tubes, load, matching, bandwidth, and power supplies. The final part is a review of what has been accomplished so far and what the authors suggest could be accomplished in the future to improve output, obtain higher frequencies, broader bandwidths, or reduce the noise level.

This book should indeed be of very great interest and value to all concerned with the development of velocity modulation tubes, and this has played, since the pioneering work of the Varian brothers, and continues to play, an important part in microwave techniques. It is clearly written, illustrated, indexed, and very well presented by one of the best French publishers of technical books. It is to be hoped that a translation will be made of this remarkable work into English, to make it available to a wider circle of students, engineers, and scientists specializing in this field or interested in related subjects.

A. G. CLAVIER

Federal Telecommunication Laboratories  
Nutley, N. J.

# Books

## TV and Electronics As a Career by Ira Kamen and Richard H. Dorf

Published (1951) by John F. Rider Publisher, 480 Canal Street, New York 13, N. Y. 304 pages + 6-page index + 15-page appendix + x pages. 136 illustrations. 5½ X 8½. \$4.95.

Ira Kamen is the Director of Electronics, Brach Manufacturing Corporation, Newark, N. J. Richard H. Dorf is an Audio and Television Consultant, New York, N. Y.

The scope of this new book includes detailed information of what must be known and learned in order to qualify for employment in almost every department of radio and electronics. In the main, the class of readers to which the book will appeal are high school and junior college students desiring authoritative information about what to study and how to go about securing a position in the wide field of radio and electronics. It is a readable work despite a considerable amount of repetition unavoidable in a book with five contributors.

The main divisions of the text include: selecting a career in TV and electronics; television broadcasting; AM and FM broadcasting and communications; radio and television manufacturing; electronic engineering; television servicing; and electronics in the armed services. The excellent illustrations in each of the chapters are helpful. The chapter on TV broadcasting, by J. R. Poppele, the experienced chief engineer of WOR-TV, might perhaps have appeared to better advantage as one of the later chapters, rather than as the second chapter of the book.

The need for guide books of this kind becomes evident with the authors' statement that the number of engineering graduates decreased by approximately fifty per cent between the years 1946 and 1950, and that a further decline is anticipated in the next two or three years. The situation would seem to be serious when it is declared that "the need for service personnel will outstrip any possible supply." One cause cited for the dearth of competent applicants for positions is "the high personal requirements." It may be that radio and TV can profit from the experience in training men of older arts such as telegraphy, telephony, and railroad engineering. Writing about assistant chief engineers in broadcasting, Mr. Poppele states, "An engineering degree is not a necessity; indeed, few assistant chiefs hold them."

In obtaining the requisite knowledge to qualify for employment in important broadcast stations and studios, emphasis is placed upon the advice to get a start at a small station, anywhere, and to learn the techniques and routines on a small scale. As much time as possible should be devoted to studying radio and television textbooks and to reading current trade journals in the field.

This book is of value to those who seek information about the requirements of employment in radio and TV, but it also contains a considerable amount of solid information for men already established in any of the various departments.

DONALD MCNICOL  
Communication Engineer  
25 Beaver Street  
New York, N. Y.

## Radio and Television Receiver Circuitry and Operation by Alfred A. Ghirardi and J. Richard Johnson

Published (1951) by Rinehart Books, Inc., 232 Madison Avenue, New York 16, N. Y. 621 pages + 19-page index + 27-page glossary + xvi pages. 411 figures, 6 X 9. \$6.00.

Alfred A. Ghirardi is a radio and electronic engineering consultant and a technical writer and editor. J. Richard Johnson is a technical editor at Rinehart Books, Inc., New York, N. Y.

This is a new and up-to-date book, written primarily for servicemen, but covering such a wide range of subjects that it would be a valuable reference book for a design engineer, since many engineers allow themselves to become so specialized in one phase or another of electronic development that they lose sight of what is occurring in related fields.

The subjects covered are as follows: Amplitude modulation and AM signals, frequency modulation and FM signals, rf amplifiers and trf receivers, am super-heterodyne receivers, AM detector and avc systems, FM receivers, pushbutton tuning and afc systems, af amplifiers, loudspeakers, radio receiver power supply systems, tv principles and the tv receiver, receiving antenna systems, home recorders, phonopickups and record players, automatic record changers, and the mechanical construction of receivers.

The authors have done an excellent job of describing and explaining this subject matter while using an absolute minimum of mathematics.

There are rather obvious errors in two or three of the schematic diagrams (such things as blocking capacitors and grounds omitted) which would not ordinarily deserve comment if the book were not intended primarily for readers who might not realize that the grounds and blocking condensers should be there. Also, the section on oscillator tuning and tracking is somewhat misleading in that it gives the impression that all receivers use only two point tracking, while, as a matter of fact, practically all receivers with equal capacity-tuning gang sections are designed to track at three points, particularly in the am broadcast tuning range.

Aside from these minor points, the book should be of valuable assistance to servicemen, technicians, and those who wish to gain some knowledge of present-day radio and television without delving too deeply into the mathematics of the principles involved.

ALDEN PACKARD  
American Radio and Television, Inc.  
P.O. Box 328  
North Little Rock, Arkansas

## Fundamentals of Acoustics by Lawrence E. Kinsler and Austin R. Frey

Published (1950) by John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y. 499 pages + 5-page appendix + 3-page glossary + 5-page index + vii pages. 165 figures. 5½ X 8½. \$6.00.

Lawrence E. Kinsler and Austin R. Frey are professors of physics, United States Naval Postgraduate School, Annapolis, Md.

This book is intended as a text for graduate students in physics or electrical engineering

rather than as reference material only. Consequently, there is much attention given to the tutorial aspects of the presentation. The physical situations are given much more attention than are accorded purely analytical considerations; the numerous illustrations and problems are particularly useful.

The scope of the text covers in similar order the topics that Morse has in his more mathematical "Vibrations and Sound." However, Kinsler and Frey have placed greater emphasis on the mechanism of the physical picture, thus making it easier reading for the student whose background is primarily engineering. Although this point of view sometimes leads to minor lapses from rigor, the presentation, on the whole, is sufficiently complete and clear in its purpose. There are few repetitions, and no glaring inconsistencies.

One of the valuable features is a discussion of loudspeakers, microphones, and horns. It is much more thorough than Morse, and more basic than that found in Olson's "Elements of Acoustical Engineering." Nevertheless, the text fails to integrate its treatment with the realities of the design, construction, testing, performance, and use of these devices. Audio engineers will still have to rely on the journal literature for much of the information on these instruments.

A useful chapter on absorption in tubes, porous solids, and fluids is included in this book. Both impedance and propagation concepts are utilized. The section on psychoacoustics is conventional, with emphasis on the difference of loudness, loudness level, and intensity. Architectural acoustics is presented more or less as a summary of useful results from the work of Morse and Bolt. The reviewer would have preferred more attention given to the treatment of underwater acoustics since it appears too restricted in security and space considerations. However, the following section on ultrasonics does give much that is of additional interest in underwater sound. Tables of constants, functions, and symbols conclude the book.

Few errors or controversial statements are found in the book, and the terms used follow the recommendations of the ASA; however, the use of "magnetomotive impedance" for the motional mechanical impedance seems misleading. An interchanged parenthesis and exponent of 2 on page 42 is an obvious error; the effect of standing waves in speaker cabinets causes less change in the radiation than is implied by the statements on page 288; and, finally, the term dbm could well have been introduced on page 352.

On the whole, the text offers a somewhat clearer and more detailed exposition than similar ones. The reviewer believes that engineers could use this for reference as well as for teaching.

VINCENT SALMON  
Stanford Research Institute  
Stanford, Calif.

# Abstracts and References

Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research, London, England, and Published by Arrangement with That Department and the *Wireless Engineer*, London, England

NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the IRE.

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The number in heavy type at the upper left of each Abstract is its Universal Decimal Classification number and is not to be confused with the Decimal Classification used by the United States National Bureau of Standards. The number in heavy type at the top right is the serial number of the Abstract. DC numbers marked with a dagger(†) must be regarded as provisional.

## ACOUSTICS AND AUDIO FREQUENCIES

**534.2:551.556** **1**  
Wind Noise and the Transmission of Sound in the Open Air—F. Spandöck. (*Z. angew. Phys.*, vol. 3, pp. 228–231; June, 1951.)

**534.231** **2**  
The Radiation of Pulses by Plane Piston Diaphragms in a Rigid Wall—F. A. Fischer. (*Acustica*, vol. 1, no. 1, pp. 35–39; 1951. In German.) When pulses are radiated by a piston diaphragm, direction-dependent distortion occurs because the propagation of the various spectral components varies in accordance with the frequency dependence of the radiation pattern. Calculation shows that a radiated unit pulse can be considered as composed of individual pulses from elementary areas of the diaphragm, and gives a representation of the shape of the diaphragm. For a pulse of arbitrary shape, the resultant is a product depending on both diaphragm shape and pulse shape.

**534.231+621.396.67]:778.3** **3**  
A Photographic Method for Displaying Sound-Wave and Microwave Space Patterns—W. E. Kock and F. K. Harvey. (*Bell Sys. Tech. Jour.*, vol. 30, pp. 564–587; July, 1951.) Description of the method, with many illustrations of actual sound-wave and microwave fields. A similar probe method, for recording on Teledeltos paper, has been described by Iams (3590 of 1947).

**534.232:534.321.9** **4**  
Construction of High-Power Ultrasonic Transmitters—E. Skudrzyk. (*Elektrotech. u. Maschinb.*, vol. 68, pp. 173–178 and 202–212; April 1 and 15, 1951.) Discussion of both quartz and magnetostriction oscillators. Suitable

The Annual Index to these Abstracts and References, covering those published in the PROC. I.R.E. from February, 1950, through January, 1951, may be obtained for 2s.8d. postage included from the *Wireless Engineer*, Dorset House, Stamford St., London S.E., England. This index includes a list of the journals abstracted together with the addresses of their publishers.

able types of holder for high-power quartz oscillators are described, and an oscillator transmitting waves through a duralumin membrane, for therapy applications, is illustrated. Simple equivalent-circuit theory of quartz oscillators is outlined and more rigorous theory is considered. Equivalent-circuit theory is also given for magnetostriction oscillators and a numerical example is calculated. Methods of measuring the output of ultrasonic oscillators are indicated.

**534.232:534.321.9** **5**  
An Efficient Low-Power Ultrasonic Generator—F. Pirker. (*Radio Tech.* (Vienna), vol. 27, pp. 175–180; April, 1951.) Description of the construction and circuit arrangement of a generator which provides an output of 50 w at an electroacoustic efficiency of 60 per cent. Full details are given of the preparation and mounting of the quartz crystal, which is energized from a Hartley circuit using a 40-w pentode.

**534.321.9** **6**  
Ultrasonics in Air, and Applications—F. Canac and V. Gavreau. (*Acustica*, vol. 1, no. 1, pp. 2–16; 1951. In French.) Electrodynamic and magnetostrictive generators and receivers are described, and investigations of the reflection and diffusion of ultrasonic waves by cylinders and polycylindrical surfaces are reported. Practical acoustical applications discussed include the study of hall acoustics by means of models.

**534.321.9:061.3** **7**  
Ultrasonics in Fluids—E. G. Richardson. (*Nature* (London), vol. 168, pp. 106–107; July 21, 1951.) Brief report of an international conference held in Brussels in June, 1951. About thirty-five papers dealing with physical measurements and theories in the field of ultrasonics were presented.

**534.321.9:534.373]:538.221** **8**  
The Influence of Magnetization of Ultrasonic Attenuation in a Single Crystal of Nickel or Iron-Silicon—Levy and Truell. (*See* 169.)

**534.44** **9**  
An 8000-c/s Sound Spectrograph—O. Gruenz. (*Bell Lab. Rec.*, vol. 29, pp. 256–261; June, 1951.) Spectral density in 45-cps and 300-cps bandwidths at frequencies up to 8 kc is permanently recorded on charts. Energy distribution with frequency is presented in two ways: (a) as discrete horizontal markings corresponding to different frequencies, for any selected 5-ms period of integration, with a maximum of 35 db relative amplitude; (b) as a continuous record of intensity, indicated by relative darkness of trace, in a frequency/time rectangular-co-ordinate framework.

**534.75** **10**  
Nonlinear Characteristics of the Ear—G. Haar. (*Funk u. Ton.*, vol. 5, pp. 248–257; May, 1951.) Comparative tests of the response of the ear to two pure notes of different frequencies  $f_1$  and  $f_2$  received simultaneously, show that difference tones formed in the ear are physically real vibrations which occur even when they are inaudible. The predominant difference frequency is  $2f_1 - f_2$ .

**534.833.1** **11**  
A Tentative Method for the Measurement of Indirect Sound Transmission in Buildings—E. Meyer, P. H. Parkin, H. Oberst, and H. J. Purkis. (*Acustica*, vol. 1, no. 1, pp. 17–28; 1951. In English.)

**534.845.2** **12**  
Acoustic Behavior of a Porous Material—A. Bressi and G. G. Sacerdote. (*Alta Frequenza*, vol. 20, pp. 28–33; February, 1951.) Measurements are reported of the acoustic absorption of "betamianto." The results differ from those for other porous materials in that an absorption maximum is exhibited at low frequencies even for a thin layer.

**534.846** **13**  
Acoustics and Sound Exclusion—W. A. Allen and P. H. Parkin. (*Arch. Rev.* (London), vol. 109, pp. 377–384; June, 1951.) Survey of the planning, structure, and finishing materials of the Royal Festival Hall, London, with consideration of both the internal acoustics of the auditorium and the exclusion of noise from the outside.

**534.846.6** **14**  
Investigation of Sound Diffusion in Rooms by Means of a Model—T. Somerville and F. L. Ward. (*Acustica*, vol. 1, no. 1, pp. 40–48; 1951. In English.) An experimental comparison was made of the effects produced by rectangular, semicylindrical- and triangular-section diffusing elements applied to the room walls. The investigation covered both steady-state and pulse operation. All three types of diffuser caused reduction of irregularity in both types of characteristic, the effect produced by the rectangular-section diffusers being greatest.

**621.395.61/.62** **15**  
Standards of Transducers: Definitions of Terms, 1951—(PROC. I.R.E., vol. 39, pp. 897–899; August, 1951.) Reprints of this Standard, 51 IRE 20 S2, may be purchased while available from the Institute of Radio Engineers, 1 East 79 Street, New York 21, N. Y., at \$0.50 per copy.

**621.395.61/.62:621.395.92** **16**  
Acoustic Transducers for Hearing Aids—W. Güttner. (*Fernmeldeleth. Z.*, vol. 4, pp. 227–234; May, 1951.) A review of piezoelectric

transducers. For the production of crystal microphones, the most suitable materials are Rochelle-salt and ammonium-phosphate crystals, and polarized BaTiO<sub>3</sub> ceramic. The properties of such microphones are analyzed and their parameters evaluated. For crystal earpieces using Rochelle salt, all possible constructions are described. From their mechanical equivalent representations, the frequency characteristics of the sound pressure are calculated and compared with measurement data.

621.395.61:621.385.82.029.3 17  
Increasing the Efficiency of the High-Power Thermionic Cell by Superposition of a Strong Field obtained from a High Voltage of High Frequency—Klein. (See 280.)

621.395.616 18  
Electrical Input Resistance of Capacitor Microphone—U. Kirschner. (*Arch. elekt. Übertragung*, vol. 5, pp. 273-278; June, 1951.) Calculation of the effective resistance is based on the work of Braun (1087 of 1945) and Weymann (470 of 1944). The results are applied to determine the parameters of a capacitor microphone to be used as a sound-pressure receiver with a circular characteristic.

621.395.623.7 19  
Progress in the Development of Electrodynamic Loudspeakers—G. Buchmann and K. Kipfmüller. (*Fernmelde- u. Z.*, vol. 4, pp. 253-261; June, 1951.) The frequency response curve, the sensitivity, and the nonlinear distortion together give a good idea of the quality of a loudspeaker. Suitable methods for determining these quantities are described. The optimum response curve is found to be one which falls off at both the lower and the higher frequencies. With suitable design, cheap loudspeakers can be produced with a good response curve over a wide band of frequencies.

621.395.623.7 20  
Acoustic Boosting of the Lower Audio Frequencies by Means of Bass Resonators with Phase Inversion—H. Gemperle. (*Radio Tech. (Vienna)*, vol. 27, pp. 245-249; June, 1951.) The method makes use of a resonator forming part of the loudspeaker housing, and coupled acoustically to the back of the vibrating membrane. Optimum dimensions of the resonator are calculable for any particular loudspeaker. Practical tests showed an increase in loudness of frequencies in the range 30 to 100 cps of about 8 db when the resonator was designed for a frequency of 60 cps.

621.395.623.7 21  
Acoustic Coupling of the Diaphragms in Duo-Cone Loudspeakers—G. B. Madella. (*Alta Frequenza*, vol. 19, pp. 267-276; October-December, 1950.) Consideration of an idealized case indicates that radiated power as a function of diaphragm velocity is appreciably affected by the degree of coupling.

621.395.625+621.396.62:061.4 22  
The Radio Exhibition at the Vienna Spring Fair—(See 250.)

621.395.625.3 23  
Recording Demagnetization in Magnetic Tape Recording—O. W. Muckenhirn. (*Proc. I.R.E.*, vol. 39, pp. 891-897; August, 1951.) "An analysis of the magnetic tape recording process employing supersonic excitation is presented by considering the effect of the spatial distribution of the magnetic field around the recording head air gap on the magnetic history of an unmagnetized element of tape as it tracks across the recording head. This leads to an effect which is termed "recording demagnetization," and serves to explain certain performance characteristics. An experimental technique developed for the measurement of this recording demagnetization is described, as is the method of measuring the air-gap field distribution. Finally, the correlation of the

measurements of the recording demagnetization with normal recording performance characteristics is reported."

534.852:621.395.625.3 24  
Magnetic Recording—M. Alixant. (*Radio Tech. Dig. (France)*, vol. 5, no. 3, pp. 147-161; 1951.) A bibliography of articles and patents complementary to that included in the book "Magnetic Recording" by Schuh and Mikhnewitch published in 1950.

621.395.625.3 25  
The R.C.A. 10794 High-Fidelity Magnetic Recording Head—M. Rettinger. (*Radio Tech. Dig. (France)*, vol. 5, no. 3, pp. 131-141; 1951.) French version of 807 of 1951.

621.396.645.029.4:621.018.78†:534.861 26  
Audio-Frequency Amplifiers with Adjustable Non-linearity (Distortion Circuits)—G. Hoffmann. (*Funk. u. Ton*, vol. 5, pp. 169-176; April, 1951.) Two amplifier circuits having nonlinear characteristics largely independent of frequency, and designed for investigation of the audibility of distortion tones produced in the transmission of music, are described.

#### ANTENNAS AND TRANSMISSION LINES

621.315.2 27  
Interaxial Spacing and Dielectric Constant of Pairs in Multipaired Cables—J. T. Maupin. (*Bell Sys. Tech. Jour.*, vol. 30, pp. 652-667; July, 1951.) Experiments show that so far as the interaxial spacing and dielectric constant are concerned, actual cable conditions can be represented by two parameters of an ideal cable. These two parameters can thus be readily obtained for a commercial cable by calculation from the measured inductance, mutual capacitance, and capacitance to ground of the pair.

621.315.2:621.396.97 28  
Modern Broadcasting Cables to C.C.I.F. Recommendations—E. A. Pavel. (*Fernmelde- u. Z.*, vol. 4, pp. 150-157; April, 1951.) The essential features of the former and the recent C.C.I.F. recommendations are compared and tabulated, with particular reference to the widening of the transmission band required in connection with the introduction of usw broadcasting.

621.392:621.396.677 29  
Approximation Methods in Radial Transmission Line Theory with Application to Horns—A. E. Laemmel, N. Marcuvitz, and A. A. Oliner. (*Proc. I.R.E.*, vol. 39, pp. 959-965; August, 1951.) "The radial transmission line theory provides a rigorous description of the propagation of electromagnetic energy in certain cylindrical regions. The complexity of direct calculation may be avoided by a simpler, although approximate, description based on the asymptotic identity of radial and uniform transmission line formulas at large radii. Approximate expressions are developed for input admittance, frequency sensitivity, and higher mode interaction effects on radial lines. Estimates of the order of accuracy are included, and applications are made to sectoral horns."

621.392.09 30  
Propagation of an Electromagnetic Wave Guided by a Metal Surface with Dielectric Coating—J. F. Colin. (*Onde élect.*, vol. 31, pp. 245-256; May, 1951.) Propagation along a cylindrical conductor is considered, assuming a perfect conductor and a loss-free dielectric. The conditions are deduced for a single possible mode of propagation, the TM<sub>01</sub> mode. If the frequency, or the dielectric constant, or the thickness of the dielectric are increased beyond certain limits, conditions are obtained in which other modes are possible. The effective cross section of the conductor in transmitting power is much greater than its physical dimensions,

owing to the distribution of energy in the surrounding fields. Expressions are deduced for the effect of losses and for the maximum power transmitted, and curves are drawn to assist in the solution of practical cases. The conditions for propagation of TE waves are briefly discussed.

621.392.2.09+621.396.11 31  
Characteristic Impedance, Power, Voltage and Current in Transmission along Lines, in Waveguides and in Free Space—O. Zinke. (*Funk u. Ton*, vol. 5, pp. 225-238; May, 1951.) Neglecting losses and assuming purely progressive waves of sinusoidal form, the following relations are derived: (a) the ratio of the mean field strengths  $E_m/H_m$  at any point in the field cross section perpendicular to the direction of propagation is independent of the dimensions of the system, and is termed the elementary characteristic impedance  $z_0$ ; (b) the characteristic impedance  $Z_0$  of the system is equal to  $z_0 h_m/b_m$ , where  $h_m$  is the effective height, and  $b_m$  the effective breadth of the field; (c) the power transfer  $N = E_m \cdot H_m \cdot h_m \cdot b_m$ , i.e., the product of mean power per cm<sup>2</sup> and the effective cross section  $S$  of the field. For rectangular waveguides,  $S$  agrees exactly with the actual cross section. For coaxial cables and narrow strip conductors the agreement is only approximate.

621.392.26† 32  
Experimental Investigation of the Reflections produced in a Waveguide by any Dielectric—L. R. Noriega. (*Radio franc.*, no. 6, pp. 1-9; June, 1951.) Reprint. See 3038 of 1949.

621.392.26† 33  
A Study of Single-Surface Corrugated Guides—W. Rotman. (*Proc. I.R.E.*, vol. 39, pp. 952-959; August, 1951.) Two types of structure were investigated experimentally as transmission lines and as radiators: (a) a flat grooved plate fed by a waveguide; (b) a circular corrugated cylinder fed by a coaxial line. Modification of type (b) results in a spirally grooved rod with similar properties. Measured field parameters agree with those predicted from theory. For properly designed structures, the energy is essentially bound to the corrugated surface. Little radiation occurs, and the attenuation of the traveling wave is due mainly to losses in the metal. The effect of filling the corrugations with solid dielectric is analyzed.

621.392.26†:621.39.09 34  
Refraction of Evanescent Waves—N. Carrara. (*Alta Frequenza*, vol. 19, pp. 164-174; August, 1950.) An account of experiments in which evanescent centimeter em waves are incident on a plane separating two dielectrics, the reflected wave being also evanescent, while the refracted wave is of ordinary type. The results indicate that Snell's laws and Fresnel's formulas are valid even when the angles of incidence and reflection are complex.

621.392.26†:621.39.09 35  
Propagation of U.H.F. Electromagnetic Waves in Conducting Waveguides of Rectangular Cross-Section: Part 1—H. Frühauf. (*Elektrotechnik (Berlin)*, vol. 5, pp. 263-269; June, 1951.) Under certain conditions, energy is propagated in tubular conductors as plane waves. Vector analysis is applied to derive simple formulas, applicable by mathematical technicians to practical cases, for the field components of  $E$  and  $H$  waves, the limiting frequency, the wavelength in the rectangular waveguide, and the phase velocity.

621.396.67 36  
Progressive-Wave Aerials—A. F. Huerta. (*Rev. Telecomun. (Madrid)*, vol. 6, pp. 23-37; June, 1951.) Theory is given relating to a progressive-wave antenna terminated by its characteristic impedance. The gain is calcu-

lated, and the effect of finite ground conductivity is discussed. The results are applied to explain the properties of rhombic antennas and of the Marconi series-phase antenna.

- 621.396.67 37  
A Short Proof that an Isotropic Antenna is Impossible—H. F. Mathis. (Proc. I.R.E., vol. 39, p. 970; August, 1951.)

- 621.396.67 38  
Tuning and Matching of Aerials—A. F. Huertas. (Rev. Telecomun. (Madrid) vol. 6, pp. 38-49; March, 1951.) Various methods of tuning and matching are illustrated and analyzed. Particular cases considered include the excitation of a directive group of antennas and applications of "balun" devices.

- 621.396.67:621.316.761.2 39  
Increase of the Bandwidth of Aerials by means of Compensation Circuits—R. Goubelin. (Onde élect., vol. 31, pp. 233-244; May, 1951.) The problem is reduced to that of determining an antenna and associated network such that, in the complex diagram of the system, its input impedance falls within a circle defined by the magnitude of the maximum permissible SWR in the feeder line. Using this construction, the general cases are discussed of the matching of any antenna to a network, and of the increase of antenna bandwidth by compensation circuits, or by sections of transmission lines. Self-compensated arrays are described, and compensation methods are demonstrated by practical examples.

- 621.396.67:621.397.5 40  
Directional Operation Planned for KRON-TV—R. A. Isberg. (Tele-Tech., vol. 10, pp. 26-27, 76; July, 1951.) An eight-section channel-four R.C.A. TF-DA "Super-Gain" antenna is mounted on a 200-foot tower on San Bruno Mountain, four miles inland from the San Francisco coast. Radiation is at present omnidirectional, but may be modified to give 100 kw radiated power inland and 3kw radiated power towards the ocean. Feeder and antenna assembly are described in outline.

- 621.396.67+534.231]:778.3 41  
A Photographic Method for Displaying Sound-Wave and Microwave Space Patterns—Kock and Harvey. (See 3.)

- 621.396.67.029.51 42  
A Long-Wave Aerial—L. C. Garcia. (Rev. Telecomun. (Madrid), vol. 6, pp. 82-85; March, 1951.) Description of an antenna forming part of the equipment of the new Spanish Transradio station at Parets del Vallés, Barcelona. The antenna is of the inverted-L type, the horizontal portion having a mean height of 86 m and being supported from steel lattice masts. The operating frequency of 79.15 kc will give a working radius of 1,750 km with fields  $> 30 \mu\text{v/m}$ , sufficient for reception on an undulator.

- 621.396.67.029.62 43  
Transmitting Aerials for U.S.W. Broadcasting—W. Berndt. (Telefunken Ztg., vol. 24, pp. 6-21; March, 1951.) The characteristics desirable in antennas for broadcasting in the frequency band 87.7 to 100 mc are enumerated, and the properties of simple and beamed radiator elements are described, the conditions being determined for selection of the optimum distance between the elements. Methods of feeding multi-element antennas are described. Practical installations of U-antennas and double-slot antennas are illustrated and discussed.

- 621.396.67.029.63 44  
Sideline Helix U.H.F.-TV Transmitting Antenna—L. O. Krause. (Electronics, vol. 24, pp. 107-109; August, 1951.) A traveling-wave helical antenna giving a power gain of 20 at 500 mc, with a bandwidth of 20 mc, consists of

four vertically stacked bays, each including a right- and a left-hand helix placed end to end and fed at their junction. Beam tilt can be produced by mechanically rotating one portion of the antenna relative to the other.

- 621.396.67.029.64 45  
U.H.F. Dipoles—P. E. Vincelet. (Rev. tech. Comp. franç. Thomson-Houston, no. 15, pp. 43-49; April, 1951.) In the construction of linear arrays, dipoles, including slotted dipoles, are particularly useful. A simplified method of calculating the characteristics of dipole arrays is outlined, and admittance characteristics of dipoles used under various conditions are given.

- 621.396.671 46  
[E.m.] Waves in a Flat Horn—B. L. Rozhdestvenski. (Compt. Rend. Acad. Sci. (URSS), vol. 77, pp. 221-224; March 11, 1951. In Russian.) A mathematical discussion is presented of the excitation of a flat horn by waves, either plane or cylindrical, arriving from a waveguide coupled to the horn. A conformal transformation is used which enables the problem to be reduced to a differential equation with partial derivatives. With certain simplifying assumptions, a finite solution of this equation can be obtained. The solution is sufficiently accurate for practical purposes, but its accuracy can be increased by using the method of successive approximations. The method is applicable also to circular and coaxial horns.

- 621.396.676 47  
Radio-Frequency Current Distributions on Aircraft Structures—J. V. N. Granger and T. Morita. (Proc. I.R.E., vol. 39, pp. 932-938; August, 1951.) Models having scale factors of 43:1 to 72:1 were used, and the magnetic field surrounding the excited model was explored by means of a small loop. The results are shown diagrammatically for several types of aircraft excited by antennas of different types.

- 621.396.676 48  
Experimental Study of Slot Aerials—J. Desauty and R. Rocherolles. (Radio franç., no. 6, pp. 14-17; June, 1951.) Signals from a slot antenna located under an aircraft, were received by a similar antenna on the ground. Polar diagrams are given. The results are in conformity with theory.

- 621.396.677 49  
Lenses for Microwaves—F. L. Garrido. (Rev. Telecomun. (Madrid), vol. 6, pp. 65-75; March, 1951.) A concise review of the properties of various types of lens, including those formed of homogeneous dielectric, those with plane-parallel conductors, lenses of artificial dielectric, and others in which the index of refraction varies with distance from the axis.

- 621.396.677 50  
Path-Length Microwave Lens—D. G. Kiely. (Wireless Eng., vol. 28, pp. 248-250; August, 1951.) Experimental investigation of the E-plane radiation patterns of a cylindrical path-length lens shows an asymmetric main beam. This cannot be caused solely by an asymmetric distribution of field amplitude across the aperture, but must be due also to the presence of asymmetric phase curvature, contrary to the experience of Kock (3058 of 1949). The path-length lens, although having many H-plane applications, is fundamentally unsuited for phase-correction in the E-plane.

- 621.396.679.4 51  
New Method of Top Feed for Antifading Broadcasting Masts—H. Graziadei. (Fernmelde-techn. Z., vol. 4, pp. 159-167; April, 1951.) Methods adopted to reduce fading effects in the service area of a broadcasting antenna are discussed, and the advantages of feeding an antenna at a point near the top are pointed

out. Practical methods for top feeding a vertical antenna are described, and the results of measurements of the vertical distribution of radiation for antennas fed at the foot and top, respectively, are shown in graphs.

- 621.392.26† 52  
Felder und Wellen in Hohlleitern [Book Review]—H. H. Meinke, Publishers: R. Oldenburg, München, Germany, 1949, 148 pp., 15 DM. (Frequenz, vol. 5, p. 53; February, 1951.) A detailed exposition in relatively simple form of the propagation of waves in waveguides. Useful for practising engineers as well as for students.

## CIRCUITS AND CIRCUIT ELEMENTS

- 621.3.012.3:621.396.621.54 53  
New Diagrams for 'Ganging' Calculation—H. Kerbel. (Funk u. Ton, vol. 5, pp. 287-296; June, 1951.) Diagrams facilitating the determination of the parameters of ganged capacitors in superheterodyne receivers are given. From the data of the variable capacitors, completely independent parameters can be derived. The values of the parallel (trimmer) and series capacitors are obtained by multiplication of the corresponding parameters by the capacitance variation  $\Delta C$  of the variable capacitor, the inductance by division by  $\Delta C$ . The magnitude and distribution of the distributed capacitance are taken into account. A method of measuring the error curve is also described.

- 621.3.015.7†:621.387.4† 54  
A Mechanical Kick-Sorter (Pulse Size Analyzer)—S. G. F. Frank, O. R. Frisch, and G. G. Scarrott. (Phil. Mag., vol. 42, pp. 603-611; June, 1951.) Each pulse causes a small steel ball to be propelled along an inclined board; the ball describes a parabolic path, which is determined by the pulse amplitude, and lands in one of thirty parallel grooves. A histogram of the pulse size distribution is thus built up. The mechanical construction and associated electronic circuits are described. The latter eliminate pulses which are either too large or too small to be recorded, or which follow too closely upon the previous pulse.

- 621.3.015.7†:621.3.018.78† 55  
Pulse Distortion—S. H. Moss. (Proc. IEE, vol. 98, pp. 398-400; September, 1951.) Summary of IEE Monograph No. 5. For a linear low-pass process, certain invariants which completely define the pulse shape exist for any input pulse. These are always increased by the same invariants imposed by the system to yield the invariants of the output waveform. The pulse invariants correspond to parameters used to describe statistical distributions. The theory in generalized form applies also to wave packets.

- 621.3.016.35 56  
Application of Bode's Relation to the Calculation of a Nyquist Diagram—A. Herrent and G. Novgorodsky. (HF (Brussels), no. 9, pp. 229-236, 255; 1951.) In applying Nyquist's stability criterion to a closed system, it is necessary to know the frequency/phase and frequency/amplitude characteristics of the network over a very wide frequency range. The practical difficulties involved, especially at low frequencies, are eliminated by the use of Bode's relation which relates the phase and amplitude characteristics. A quick and easily applied graphical method is described for evaluating the integral in Bode's formula, and hence the Nyquist diagram may be drawn. The method has been verified experimentally in the case of a low-frequency amplifier with resistive feedback.

- 621.314.2:621.392.6 57  
Contributions to the Theory of the Differential Transformer—G. Schmitt. (Frequenz, vol. 5, pp. 39-44; February, 1951.) Equations

and equivalent circuits for the differential transformer are developed from the theory of six-pole networks. The stop-band attenuation is calculated and its frequency variation investigated. Design conditions are discussed for making the stop-band attenuation as great as possible.

621.315.592†:537.312.6 58

Experiments on Thermistors of Italian Manufacture—P. Lombardi and M. Vallauri. *Alta Frequenza*, vol. 20, pp. 51–67; April, 1951.) Basic theory of electronic conduction in semiconductors is outlined, and variation of resistance with temperature is considered. Measurements on specimen thermistors are reported, and the values of their time constants are deduced. Applications both familiar and unfamiliar are discussed.

621.316.726.078.3 59

U.H.F. Discriminator and its Application to Frequency Stabilization [of klystron]—G. Pircher. (*Rev. tech. Comp. franc. Thomson-Houston*, no. 15, pp. 37–42; April, 1951.) A modification of Pound's stabilization circuit (1690 of 1947) is described which avoids the use of magic-T junctions. See also 2758 of 1951.

621.316.761.2:621.396.67 60

Increase of the Bandwidth of Aerials by means of Compensation Circuits—Goubelin. (See 39.)

621.318.4 61

Mean Winding Lengths—L. Hubl. (*Elektrotechnik*, (Berlin), vol. 5, pp. 175–179; April, 1951.) Methods and formulas are given for determining the mean length of choke and transformer windings on laminated cores. Tables and diagrams enable the required values to be found directly for many practical cases without much calculation, the values in the tables being used for interpolation.

621.318.572 62

Transition of an Eccles-Jordan Circuit—J. R. Tillman. (*Radio Tech. Dig.* (France), vol. 5, nos. 3 and 4, pp. 143–146 and 203–216; 1951.) French version of 2119 of 1951.

621.318.572 63

Electronic Switch—S. F. Pinasco. (*Rev. Electr.* (Buenos Aires), vol. 39, pp. 333–335; 353; June, 1951.) Description, with detailed circuit diagram, of a switching circuit consisting of a multivibrator, which produces the voltages necessary for alternate blocking and unblocking of the signal, and an amplifier giving the required amplitude.

621.318.572:621.385.5 64

High-Speed Sampling Techniques—B. R. Shepard. (*Electronics*, vol. 24, pp. 112–115; August, 1951.) Condensed version. For full paper see *Proc. Nat. Electronics Conference* (Chicago), vol. 6, pp. 255–265; 1950. An arrangement is described which is suitable for transmitting observations from a number of measuring elements in rapid cyclic succession, using only one channel. Signals of low intensity are considered. A rotating-radial-beam-tube commutator of the type described by Skellett (3167 of 1944) is connected to the individual circuits in turn. The noise generated by this scanning operation is discussed; its magnitude determines the amount of pre-amplification required. Scanning rates of  $10^6$  elements/s are obtainable.

621.319.4 65

Working Characteristics and Performance of Ceramic Capacitors—A. Danzin. (*Ann. Radioelect.*, vol. 6, pp. 156–179; April, 1951.) The performance of capacitors of a great variety of types formed from the ceramic dielectrics previously described (132 of 1951) is discussed in detail. Manufacturing processes are described and tables are given analyzing the general characteristics; stability, dielectric

loss, endurance under varying climatic conditions, temperature coefficient, and overload characteristics.

621.392 66

The Effect of Alteration of Network Parameters in a Particular Type of Reactance Network on the Resonance Frequency of the Network—T. O'Callaghan. (*Frequenz*, vol. 5, pp. 44–47; February, 1951.) The networks considered are of low-pass shunt-capacitance ladder type, with  $n$  unequal capacitances and  $n+1$  unequal inductances. Two cases are distinguished: (a) where available component magnitudes do not coincide exactly with design requirements for a desired performance of the network; (b) where it is desired to eliminate an undesired resonance occurring in an existing network. The method developed is based on considering half-sections of the network as separate resonant systems.

621.392.001.4 67

Determination of Amplitude and Phase Characteristics of Linear Networks by means of Square Waves—Müller. (See 209.)

621.392.5:512.831 68

Transformation of the Quadripole-Network Matrix to the Diagonal Form—H. Schulz. (*Arch. elekt. Übertragung*, vol. 5, pp. 257–266; June, 1951.) Description of a method which systematizes all types of linear quadripole, with application to a low-loss transformer with fixed coupling.

621.392.52 69

The Four-Circuit Band-Pass Filter and Bandwidth Switching by Back Coupling—G. Hentschel. (*Funk. u. Ton*, vol. 5, pp. 281–286; June, 1951.) The formulas for calculating the resonance curves of four-circuit filters with arbitrary values of coupling and damping are derived. By introducing auxiliary coupling from the fourth to the first circuit, bandwidth switching is effected very simply. The filter then approximates to a two-circuit filter with enhanced coupling.

621.392.52 70

Transfer Properties of Single- and Coupled-Circuit Stages With and Without Feedback—J. W. Muehlner. (*Proc. I.R.E.*, vol. 39, pp. 939–945; August, 1951.) "Universal curves of the reciprocal of the complex response function are studied for systems with one or two tuned circuits. The normalized parabola for two circuits is presented with a net of loci for the origin of co-ordinates within it. The ratio  $Q_1/Q_2$ , the amount of fixed detuning, the amount of coupling, and amplitude and phase of any additional feedback independently displace the origin with respect to its position in case of two identical, uncoupled circuits without feedback. Complex cases may be easily analyzed. Different methods incorporating regeneration or feedback loops are discussed which allow practical bandwidth control within wide limits."

621.392.52:621.395.44 71

Group-Combining Filters for Twelve and Twenty-Four Circuit Carrier Systems—D. W. Robson. (*GEC Telecommun.*, vol. 3, no. 1, pp. 45–51; 1948.) Complementary high-pass and low-pass crystal filter units are described for combining and separating the two sets of twelve channels in the 12- to 60-kc and 60- to 108-kc bands, respectively, in a twenty-four-channel carrier system. An attenuation of >40 db is achieved for the two stop bands of, respectively, 60.3 to 108 and 12 to 59.7 kc, with a pass-band loss level to within  $\pm 0.5$  db.

621.392.53 72

Waveform Systems and 'Time Equalizers'—D. C. Espley. (*Wireless Eng.*, vol. 28, pp. 251–258; August, 1951.) A new approach to the solution of circuit problems where the available transmission information is given in terms of distorted waveforms. Some classical trans-

forms relating frequency and time characteristics can be replaced by simpler algebra which enables the physical interpretation to be kept in view. The amplitude and phase characteristics of a system with unknown internal structure are evaluated simply from the nonredundant networks which are arranged to simulate the actual system waveform distortions. The insertion characteristics of the waveform-correcting networks, or "time equalizers," follow directly. The correction of some systems may require the use of both "time equalizers" and the better known "steady-state" equalizers.

621.392.6.062 73

N-Terminal Switching Circuits—E. N. Gilbert. (*Bell Sys. Tech. Jour.*, vol. 30, pp. 668–688; July, 1951.) Shannon's method of synthesis of two-terminal switching networks (2456 of 1949) is generalized to apply to  $N$ -terminal networks which use selector switches with any number of positions.

621.396.611.1 74

Constant Oscillatory Circuits for High Frequencies—K. Schreck. (*Fernmeldelech. Z.*, vol. 4, pp. 145–149; April, 1951.) The design and properties of various fixed and variable circuits are described, including ceramic components, which give a frequency constancy of the same order as that obtained with quartz crystals. The methods of compensation specially developed for new types of circuit are described.

621.396.611.1 75

Internal Resonance in Circuits containing Nonlinear Resistance—R. E. Fontana. (*Proc. I.R.E.*, vol. 39, pp. 945–951; August, 1951.) The simultaneous presence of two oscillations locked in synchronism is investigated for circuits containing a nonlinear element. Such a circuit is said to be "internally resonant," the ratio of the two frequencies being that of two integers. The solution of the appropriate equations and the conditions for stable equilibrium are discussed.

621.396.611.1 76

Oscillation Excitation in Circuit with Periodically Varying Capacitance—W. Taeger. (*Funk u. Ton*, vol. 5, pp. 300–309; June, 1951.) Starting from a particular form of the modulation function of the capacitance variation which is rich in harmonics (sawtooth function) and which has the advantage of affording an exact solution of the differential equation describing the phenomena, the conditions are investigated under which the natural damping of the circuit can be eliminated, and the currents and voltages follow a simple sine law.

621.396.611.1 77

Method of Determining the Forced Oscillations produced by Periodic E.M.F. of Arbitrary Waveform—O. M. Bogatyrew. (*Elektrotechnik* (Berlin), vol. 5, pp. 194–197; May, 1951.) A formula for the induced current is derived which involves an integral with limits convenient for calculation. The formula is developed by a simple application of the Duhamel integral.

621.396.611.3 78

Equations for the Natural Frequencies of Coupled Circuits from the Quadripole Viewpoint—H. Rukop and H. Kaiser. (*Telefunken Ztg.*, vol. 24, pp. 64–74; June, 1951.) Various simple and more complex circuits are considered, and formulas for the coupling factors are derived and tabulated together with relations between the circuit parameters. Applications of the theory to circuits involving the various types of coupling are described.

621.396.611.4 79

Separation of Degenerate Oscillation Modes in Perturbed Rectangular Cavities—F. Bosinelli. (*Alta Frequenza*, vol. 19, pp. 244–259; October–December, 1950.) A rectangular resonant cavity is considered, the walls of

which have a slight arbitrary deformation. The perturbed resonance frequencies and, in particular, the frequency displacements of two degenerate modes, are determined theoretically. The principles followed in the case of twofold degeneracy can be generalized for  $N$  degenerate modes. The frequency shifts are calculated for the two degenerate modes  $TE_{emn}$  and  $TM_{emn}$  in a rectangular cavity which has been deformed into a trapezoidal cavity by tilting one of its walls through a small angle  $\theta$ . This type of perturbation separates the two modes: to a first approximation, the relative frequency shifts are proportional to  $\theta$ . Similar results are obtained for the two modes  $TE_{102}$  and  $TE_{201}$  when they are degenerate.

**621.396.615:621.316.726 80**  
**Difference Oscillators and their Constancy**—W. Herzog. (*Arch. elekt. Übertragung*, vol. 5, pp. 279–283; June, 1951.) Arrangements are described which produce two frequencies simultaneously and, after rectification, emit the difference frequency. Bridge types of oscillator with similar or dissimilar arms are considered. In the latter case, the use of a crystal as one branch of the circuit results in high constancy of the difference frequency. A simple oscillator is also described which uses a 130-kc crystal provided with three electrodes; the resulting difference frequency is 1.3 kc.

**621.396.615.018.424† 81**  
**Seven-League Oscillator**—F. B. Anderson. (*Proc. I.R.E.*, vol. 39, pp. 881–890; August, 1951.) A bridge-type RC oscillator is described which is continuously variable over a very wide frequency range in one sweep of a two-gang linear-potentiometer control. The output is available in four phases, and the frequency is an approximately logarithmic function of the potentiometer setting. The design of the bridge is discussed in terms of circle diagrams of transmission through RC networks. Tentative frequency limits are 0.01 cps and 10 mc. Accuracy of setting and stability of frequency are discussed.

**621.396.615.029.422/426 82**  
**A Balanced RC Oscillator**—D. A. Bell. (*Electronic Eng.*, vol. 23, pp. 274–275; July, 1951.) A Wien-bridge feedback circuit with a balanced maintaining amplifier is used to produce frequencies between 0.1 and 20 cps having a very small even-harmonic content.

**621.396.615.14 83**  
**Limiting Range for the Generation of Oscillations with Grid-Controlled Valves**—L. Ratheiser. (*Radio Tech.* (Vienna), vol. 27, pp. 168–170; April, 1951.) Continuation of paper abstracted in 1819 of 1948. Circuit arrangements and construction of various types of usw oscillator are discussed.

**621.396.615.17 84**  
**Frequency Multiplier with Selective Network in the Grid Circuit**—A. Taraboletti. (*Alta Frequenza*, vol. 19, pp. 221–230; October–December, 1950.) Relative amplitudes of the various harmonics appearing in the anode circuit are calculated for the case of an aperiodic and of a selective grid circuit. Experimental results confirm the superiority of the selective arrangement.

**621.396.619.23 85**  
**Oscillator Circuits as Frequency Modulators**—Mansfeld. (*See* 297.)

**621.396.645 86**  
**Mathematical Treatment of Control Curves for Amplitude-Controlled Amplifiers**—J. Hacks. (*Telefunken Ztg.*, vol. 24, pp. 51–54; March, 1951.) The dependence of the output voltage on the input voltage is investigated (a) for linear dependence on the slope of the tube characteristic (hexode with grid-3 control), (b) for exponential dependence (pentode, or hexode with grid-1 control). Both cases admit of accurate calculation. Experimental

and theoretical curves are compared and the design of a practical IF amplifier with forward and backward control is shown.

**621.396.645 87**  
**Cathode-Follower Input Impedance**—J. E. Flood. (*Wireless Eng.*, vol. 28, pp. 231–239; August, 1951.) The input conductance  $G$  of a cathode follower with a capacitive load decreases with increasing frequency, passes through zero, and becomes negative. The circuit with the grid lead returned to a point on the cathode resistance is analyzed; an expression is obtained for the frequency at which  $G$  is zero. Methods of raising this frequency are discussed; the most satisfactory involves a series grid resistance. Experimental work with a triode-connected EF 91 is described. Discrepancies between predicted and observed behavior are attributed to Miller effect, resulting from the unavoidable anode load presented by the anode decoupling capacitor.

**621.396.645:621.392.52 88**  
**New Method of Calculating High-Frequency Filters with Tchebycheff Type of Amplification**—H. Edelmann. (*Arch. elekt. Übertragung*, vol. 5, pp. 284–292; June, 1951.) With the aid of Tchebycheff polynomials, the amount of amplification, and hence the complex amplification, is determined by choice of the null points of the reciprocal of the complex amplification. Circuit parameters can then be chosen so that the null points agree with requirements. The method is applicable to amplifiers with any number of stages and circuits. Typical examples considered are (a) single-circuit amplifier stage, (b) two-circuit amplifier stage with coupled filters.

**621.396.645.018.424† 89**  
**Design and Construction of Wide-Band I.F. Amplifiers**—L. Gérardin. (*Rev. tech. Comp. franc. Thomson-Houston*, no. 15, pp. 19–36; April, 1951.) The general design of IF amplifiers for use in radar receivers is discussed. Large bandwidth may be achieved in amplifiers of normal type by the use of certain artifices, but the method has limitations. A distributed amplifier is described which has a pass band of 10 to 150 mc at  $\pm 3$  db, with an over-all gain of 72 db. The calculation of the over-all noise factor of a radar receiver is described in an appendix.

**621.396.645.018.78† 90**  
**Nonlinear Distortion in Push-Pull Class-B Amplifiers with Choke Output**—F. Böttcher. (*Telefunken Ztg.*, vol. 24, pp. 39–48; March, 1951.) Detailed mathematical analysis of the choke output circuit, with numerical calculations for a 40-kw tube. Approximate formulas are shown to give results which are sufficiently accurate for most purposes.

**621.396.645.029.4:621.3.018.78†:534.861 91**  
**Audio-Frequency Amplifiers with Adjustable Nonlinearity (Distortion Circuits)**—Hoffmann. (*See* 26.)

**621.396.645.2.018.422† 92**  
**Calculation of High-Frequency Amplifier Circuits with Relatively Narrow Pass Band (Radio Filter Circuits)**—W. Cauer. (*Arch. Elektrotech.*, vol. 40, no. 2, pp. 88–199; 1951.) A general method of calculation is developed whereby any symmetrical frequency characteristic of an amplifier containing only single-circuit coupling networks can be realized in respect of phase and amplitude by an amplifier circuit having a prescribed number of stages with multiple-circuit coupling. Detailed treatment is given for two- and three-circuit reactive networks. Application of the method to purely resistive networks is considered.

**621.396.645.35 93**  
**D.C. Amplifier with Reduced Zero-Offset**—W. McAdam, R. E. Tarpley, and A. J. Williams, Jr. (*Electronics*, vol. 24, pp. 128–132; August, 1951.) Essentially the same paper as

published in *Proc. Nat. Electronics Conference* (Chicago), vol. 6, pp. 277–285; 1950. An amplifier for current measurement, using a calibrated 1-m  $\Omega$  woven-wire resistor, has a zero offset (i.e., input required to bring output to zero) less than 1.6 times the peak-to-peak value of thermal-fluctuation voltages, corresponding to  $10^{-12}$  a on current ranges and  $1 \mu\text{v}$  on  $2 = 10^{10} - \Omega/\text{v}$  voltage ranges. Over-all dc feedback is used.

**621.396.645.37 94**  
**Parallel Voltage Feedback**—K. H. R. Weber. (*Elektrotechnik*, (Berlin), vol. 5, pp. 180–182; April, 1951.) Series and parallel voltage feedback are discussed with the aid of diagrams, and are shown to be essentially similar in operation. Parallel voltage feedback involves two damping quantities, which can be determined from formulas given. Amplification with parallel feedback is not directly measurable, but must be calculated from a simple formula involving the two damping quantities and a certain voltage ratio. A particular case is noted in which the output voltage is zero.

**621.396.645.371 95**  
**Distortion and Power Output of Negative-Feedback Amplifier Output Valves in Class-A Operation**—R. Siegert. (*Telefunken Ztg.*, vol. 24, pp. 100–117; June, 1951.) A theoretical and experimental investigation, illustrated by many curves, of the distortion remaining after application of negative feedback, first for the case of a phase-constant external resistance, and then for a frequency-dependent external resistance such as a loudspeaker.

**621.396.645.371:621.3.015.3 96**  
**Transient Phenomena in Wide-Band Feedback Amplifiers**—O. B. Lur'e. (*Elektrotechnik*, (Berlin), vol. 5, pp. 171–174; April, 1951.) German version of 78 of 1950.

## GENERAL PHYSICS

**537.291 97**  
**On the Motion of Gaseous Ions in a Strong Electric Field: Part 1**—G. H. Wannier. (*Phys. Rev.*, vol. 83, pp. 281–289; July 15, 1951.) The Boltzmann form of the kinetic theory of gases is used to determine the motion of positive ions in a gas under the influence of a static, uniform electric field. The ion density is assumed to be vanishingly low, and the field to be of a strength such that the energy it imparts to the ions is not negligible in comparison with their thermal energy. The velocity averages are studied, rather than the details of velocity distribution.

**537.52 98**  
**Cold Emission of Electrons in Spark Gaps**—F. L. Jones and E. T. de la Perrelle. (*Nature* (London), vol. 168, pp. 160–161; July 28, 1951.) The results of measurements of the electron emission from a Ni cathode, oxidized by previous sparking in air, are interpreted as supporting the view that the electrons have their source in the oxide surface layer, and are extracted by a field process.

**537.52 99**  
**Physics of Electrical Discharge**—F. L. Jones. (*Nature* (London), vol. 168, pp. 140–142; July 28, 1951.) Report of a symposium on "Some Aspects of Discharge Physics" held on March 29 to 31, 1951, at Swansea.

**537.52 100**  
**The Distribution of Electron Energies in a Discharge constricted by its Self-Magnetic Field**—J. E. Allen. (*Proc. Phys. Soc.*, vol. 64, pp. 587–589; June 1, 1951.) The distribution of electron velocities in a high-current arc in which the radial electric field can be neglected, is shown to differ from the Maxwellian, owing to the action of the self-magnetic field. In particular, the proportion of high-velocity electrons is reduced.

## 537.521 101

**Microsecond Transient Currents in the Pulsed Townsend Discharge**—J. A. Hornbeck. (*Phys. Rev.*, vol. 83, pp. 374-379; July 15, 1951.) The variation of photoelectric emission current with time was observed using an experimental gas-filled tube and a pulsed light source. The method is useful for studying fundamental parameters and processes in the noble gases.

## 537.525 102

**Mechanism of Secondary Ionization in Low-Pressure Breakdown in Hydrogen**—F. L. Jones and D. E. Davies. (*Proc. Phys. Soc.*, vol. 64, pp. 519-527; June 1, 1951.) The breakdown mechanism was investigated by examining the dependence of the shape of cathode emission curves on the deposition of electro-positive or electro-negative atoms on cathodes of Ni, Al, Ag, Cu, and Mo. "Results are analyzed in terms of the varying effective work function of the surface due to the deposition of atoms. It is concluded that the high photoelectric emission from cathodes of low effective work function was due to low-energy photons generated in the prebreakdown currents, but that for clean metals, the secondary emission was due to impact of positive ions. Photo-emission due to any high-energy photons generated in the ionization currents was negligible in comparison."

## 537.525.5 103

**The Potential Field in and around a Gas Discharge, and its Influence on the Discharge Mechanism**—W. Finkelnburg and S. M. Segal. (*Phys. Rev.*, vol. 83, pp. 582-585; August 1, 1951.) Measurements on the cathode and anode fall regions in carbon arcs are described; the thickness of each region is  $<0.01$  cm. The distorting effect of the nonuniform space-charge distribution on the potential field is discussed. Potential probe measurements in low- and high-current carbon arcs are in good agreement with the theoretical analysis, and prove the transitional region between the distorted potential field inside and the undistorted potential field outside the discharge to be a fairly thin one.

## 537.533:538.56 104

**Radio Wave Generation by Multistream Charge Interaction**—J. Feinstein and H. K. Sen. (*Phys. Rev.*, vol. 83, pp. 405-412; July 15, 1951.) Theories of the excitation of plasma oscillations in a two-electron-beam system are reviewed. Analytical and graphical methods are used to determine the ranges of parameters within which the growth of waves is possible, taking into account the effect of thermal motion. The growth of waves is possible, within a narrow frequency range, even when the beam injection velocity is much smaller than the mean thermal velocity. Relevance to solar phenomena is discussed. A new theory is advanced of the mechanism by which the longitudinal oscillations are converted into transverse electromagnetic radiations.

## 537.533:538.56 105

**The Relativistic Theory of Electro-Magneto-Ionic Waves**—V. A. Bailey. (*Phys. Rev.*, vol. 83, pp. 439-454; July 15, 1951.) "The relativistic equations governing an ionized gas pervaded by static electric and magnetic fields, and the corresponding equations for small perturbations, are derived. The equations for plane perturbations are then obtained, and several important cases are developed in detail. Frequency bands in which growing wave modes occur are also determined. By means of certain rules of transformation, the theory is also used to study the plane waves which can occur in interpenetrating double streams of electrons. The results obtained are formally similar to those obtained for waves in an ionized gas. In the absence of static magnetic fields, and with the effects of collisions neglected, it is found that, in either an ionized

gas or in interpenetrating double streams of electrons, certain waves propagated obliquely to the drift motions may both grow and possess Poynting fluxes. These fluxes are such that certain initial disturbances can lead to the escape of amplified electromagnetic energy from an ionized medium. The exchange of momentum and energy, between the streams of electrons and ions and the growing waves, is discussed by means of the momentum-energy tensors of the charged particles and of the electromagnetic field. It is concluded that both theory and observation lend support to the hypothesis suggested previously that a notable part of cosmic noise and strong solar noise originates as electro-magneto-ionic waves in magnetized ionized regions."

## 537.533:621.385.029.63/.64 106

**Waves in Electron Streams and Circuits**—J. R. Pierce. (*Bell Sys. Tech. Jour.*, vol. 30, pp. 626-651; July, 1951.) A review of some of the assumptions made, and general problems involved, in analysis of the properties of electron streams coupled to circuits. The reasons for using a wave approach are explained. "The propagation constant of the wave is obtained in terms of the properties of the electron stream and the impedance of the circuit. Some general properties of waves are described. The importance of fitting boundary conditions in the solution of an actual problem is discussed, and examples, including that of "backward-gaining" waves, are considered."

## 537.533.8 107

**A Theory of Secondary Electron Emission from Metals**—E. M. Baroody. (*Phys. Rev.*, vol. 78, pp. 780-787; June 15, 1950.) A theory is formulated which is based on the Sommerfeld free-electron model, momentum transfer between electrons and lattice being accounted for by introducing a finite mean free path for elastic scattering. An inverse relation between emission and work function is deduced which is in qualitative agreement with experiment. The theory also accounts for the velocity distribution of the secondary electrons, and is consistent with their observed angular distribution.

## 537.533.8 108

**A Comparison of Theories of Secondary Emission**—J. J. Brophy. (*Phys. Rev.*, vol. 82, pp. 757-758; June 1, 1951.) Comparison of results deduced from the quantum-mechanical theory of Wooldridge (147 of 1940) and the free-electron theory of Baroody (107 above).

## 537.533.8 109

**Secondary Emission of Electrons from Liquid Metal Surfaces**—J. J. Brophy. (*Phys. Rev.*, vol. 83, pp. 534-536; August 1, 1951.) Curves showing the secondary-emission ratio of Bi, Ga, Pb, and Hg as a function of primary energy were obtained experimentally for the metal in both the solid and liquid states. The characteristics for the two states are similar to one another and to the curves for other pure metals. The observed maximum values of secondary-emission ratio are compared with values predicted from theory.

## 537.533.8 110

**The Application of Wooldridge's Theory of Secondary Emission**—E. M. Baroody. (*Phys. Rev.*, vol. 83, pp. 857-858; August 15, 1951.) Conclusions are reached in general agreement with those of Brophy (108 above). For Wooldridge's theory, see 147 of 1940.

## 538.123 111

**The Analytical Expressions for the Vector Potential of a Rotationally Symmetrical Magnetic Field**—A. Moussa and J. Lafoucrière. (*Compt. Rend. Acad. Sci. (Paris)*, vol. 233, pp. 139-141; July 9, 1951.)

## 538.311:621.318.423:513.647.1 112

**The Excitation of a Helical Conductor**—S. Kh. Kogan. (*Compt. Rend. Acad. Sci.*

(URSS), vol. 74, pp. 489-492; September 21, 1950. In Russian.) It is assumed that a voltage is applied to an infinitely small element of the helix at  $L=0$ . The distribution of voltage along the helix is then given by equation (2), and the boundary condition, taking into account the finite conductivity of the helix, is given by equation (3). An integral equation (3b) determining the distribution of the current is derived, and its solution is reduced to the evaluation of an integral (top of p. 491.) For practical purposes it may be assumed that only one wave is propagated along the conductor.

## 538.566 113

**Properties of Inhomogeneous Plane Electromagnetic Waves**—G. Bonfiglioli. (*Alta Frequenza*, vol. 19, pp. 259-266; October-December, 1950.) Discussion of the propagation of plane-polarized, inhomogeneous waves, i.e., with electric/magnetic field vectors not constant along the wavefront, in an isotropic unbounded space. For any frequency there is an infinite and continuous series of propagation modes. This result is related to the theory of propagation in waveguides and to the theory of total reflection.

## GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

## 523.7 114

**World-Wide Observations of Solar Activity**—(*Tech. Bull. Nat. Bur. Stand.*, vol. 35, pp. 93-95; July, 1951.) A general account of the National Bureau of Standards' system for collecting information about the various types of solar activity.

## 523.72 115

**Measurements of Solar Extreme Ultraviolet and X-Rays from Rockets by means of a CaSO<sub>4</sub>-Mn Phosphor**—R. Tousey, K. Wetanabe, and J. D. Purcell. (*Phys. Rev.*, vol. 83, pp. 792-797; August 15, 1951.) Samples of a CaSO<sub>4</sub>-Mn phosphor, which was insensitive to wavelengths above 1,340 Å were exposed to sunlight in V2 rockets. Response in the bands 0-8 Å, 1,050 to 1,340 Å, and 1,230-1,340 Å was measured, using Be, LiF, and CaF<sub>2</sub> filters. X-rays were observed on one flight which reached 128 km, during which a sudden ionospheric disturbance occurred. Energy at wavelengths between 1,050 and 1,340 Å was observed at heights down to 80 to 90 km on all four flights. Values of the total radiation intensity in two ranges of the solar spectrum are calculated for a height between 82 and 127 km. The radiation between 795 and 1,050 Å reaching this region has an intensity well above that produced by a 6,000°K black-body sun.

## 523.72:621.396.822 116

**Solar Radio-Frequency Emission from Localized Regions at Very High Temperatures**—J. H. Piddington and H. C. Minnett. (*Aust. Jour. Sci. Res., Ser.*, vol. 4, pp. 131-157; June, 1951.) The slowly varying component, S, of the solar rf radiation is correlated with sunspot data and degree of circular polarization. It is suggested that the S component is due to thermal emission from localized regions at temperatures of about 10<sup>7</sup>°K, often near sunspots. The radiation from a model hot region is examined in detail; the derived emission spectrum and polarization characteristics agree reasonably with observations. Electrons and protons would probably be emitted thermionically from the hot regions, would travel to the earth with average velocities of a few hundred kilometers per second, and could form the slow corpuscular radiation deduced from terrestrial magnetic data.

## 523.72:621.396.822 117

**Solar Noise**—M. Nicolet. (*Scientia*, vol. 85, pp. 37-41 and 71-77; March-April, 1950. In French.) A survey paper. Observations on rf waves emitted by the sun are described and discussed in relation to known solar and ter-

restrial phenomena. The noise from the quiet sun originates in the outer regions; centimeter waves originate in the chromosphere, and meter waves in the corona. When the sun is disturbed, as indicated by the appearance of sunspots, the noise level rises. With the variation of solar activity, bursts are superposed on the steady noise level. These are sometimes extremely intense, being then associated with unusual phenomena such as SW fade-outs, or eruptions of cosmic rays consisting of charged particles accelerated by the electric field induced by the varying magnetic field of the sunspots. Temperatures of the order of  $10^6$ °K for the quiet sun, and  $10^4$ °K for the most intense bursts are indicated.

523.746 "1950" 118  
Final Relative Sunspot-Numbers for 1950—M. Waldmeier. (*Jour. Geophys. Res.*, vol. 56, pp. 439-441; September, 1951.)

523.746 "1951.0/.06" 119  
Provisional Sunspot Numbers for April-June 1951—M. Waldmeier. (*Jour. Geophys. Res.*, vol. 56, p. 445; September, 1951. *Z. Met.*, vol. 5, p. 288; September, 1951.)

523.854:621.396.822 120  
Observations of the Source of Radio-Frequency Radiation in the Constellation of Cygnus—B. Y. Mills and A. B. Thomas. (*Aust. Jour. Sci. Res., Ser.*, vol. 4, pp. 158-171; June, 1951.) The position and some of the properties of this source were determined. Observed fluctuations in intensity were found to correlate with activity in the ionosphere *F* region. There is no evidence that the emission from the source varies.

523.854:621.396.822 121  
A Preliminary Survey of the Radio Stars in the Northern Hemisphere—M. Ryle, F. G. Smith, and B. Elsmore. (*Mon. Not. R. Astr. Soc.*, vol. 110, no. 6, pp. 508-523; 1950.) The positions and intensities of fifty discrete sources of radio waves were measured, using an interferometer of high resolving power operating on a wavelength of 3.7 m. The results indicate that most of these radio stars are situated within the galaxy, and are distributed with an average density comparable with that of visual stars. They were not identifiable with visual stellar bodies.

538.12 122  
On the Stability of Magneto-Hydrostatic Fields—S. Lundquist. (*Phys. Rev.*, vol. 83, pp. 307-311; July 15, 1951.) The stability of static magnetic fields in an electrically conducting liquid is investigated mathematically. Particular attention is given to the case of twisted cylindrical magnetic fields. Instabilities may be caused by the twisting when it introduces an increase of magnetic energy of the same order of magnitude as the energy of the original field. The discussion is relevant to theories of the earth's magnetic field.

538.711 123  
Aeromagnetic Survey of Vertical Intensity over the Sound with Apparatus of the BMZ Type—A. Lundbak. (*Tellus*, vol. 3, pp. 69-74; May, 1951.) The magnetometric zero balance was suspended in gimbals in an aircraft flying over the sea area between Denmark and Sweden. Comparison with measurements taken on the ground near the coasts shows that, with certain precautions, accuracies to within  $\pm 20$  gammas can be obtained.

550.38 "1951.01/.03" 124  
International Data on Magnetic Disturbances, First Quarter, 1951—J. Bartels and J. Veldkamp. (*Jour. Geophys. Res.*, vol. 56, pp. 442-444; September, 1951.)

550.38 "1951.04/.06" 125  
Cheltenham Maryland Three-Hour-Range Indices *K* for April to June, 1951—R. R. Bodle.

(*Jour. Geophys. Res.*, vol. 56, p. 445; September, 1951.)

550.384 126  
Variations of the Magnetic Field and Rotation of the Earth—N. Stoyko. (*Compt. Rend. Acad. Sci. (Paris)*, vol. 233, pp. 80-82; July 2, 1951.) From a comparison of recorded data, it is concluded that the variation of the geomagnetic field may be explained by variation of the earth's rotation, and that any rotating body should possess a magnetic field of which at least a part is due to the rotation round its axis.

550.385 127  
Principal Magnetic Storms [April-June, 1951]—*Jour. Geophys. Res.*, vol. 56, pp. 446-448; September, 1951.)

551.510.535 128  
The Modes of Formation of the Ionospheric Layers—J. H. Piddington. (*Jour. Geophys. Res.*, vol. 56, pp. 409-429; September, 1951.) Ionospheric measurements made during eclipses are analyzed and, together with recently acquired solar data, are used in a re-examination of the theories of the ionosphere. It is shown that: (a) The rates of disappearance of electrons in all the principal layers may be much higher than hitherto believed. If so, then the number of ionizing quanta needed is also greatly increased. (b) There is probably a nonsolar source of electron production in region *E* (and perhaps in region *D*). It may be the electric currents flowing in the upper atmosphere which are also manifested by fluctuations in the earth's magnetic field. (c) Solar ionizing radiation does not appear to originate (principally) either throughout the corona or near the photosphere, but in regions of rapid temperature transition in the chromosphere and lower corona. Excess emission occurs, as has been shown previously, from regions of disturbance, often near sunspots. (d) The emission spectrum of these regions may be strong in the quasi-Lyman spectrum of He II and in X-rays of wavelengths ranging down to about 3Å. During flares, X-rays of wavelength less than 1Å may be emitted. (e) The *F*<sub>1</sub> and *F*<sub>2</sub> ionospheric layers may be accounted for if minor modifications of existing theories are made. The *E* and *D* layers may be formed by quanta of a few hundred and a few thousand electron volts, respectively, originating in the chromospheric transition region.

551.510.535 129  
A Self-Consistent Treatment of the Oxygen Dissociation Region in the Upper Atmosphere—H. E. Moses and Ta-You Wu. (*Phys. Rev.*, vol. 83, pp. 109-121; July 1, 1951.) A theory is suggested according to which the temperature and the concentrations of oxygen atoms and molecules at a height of 100 to 140 km can be expressed as functions of the height from a knowledge of the temperature and its gradient at a certain height. The theory is illustrated by an actual calculation. The result obtained differs considerably from those of previous researches.

551.510.535 130  
Statistical Nature of the Ionosphere—Ya. L. Al'pert and A. A. Aynberg. (*Zh. Eksp. Teor. Fiz.*, vol. 21, pp. 389-400; March, 1951.) The electromagnetic field of a single signal reflected from the ionosphere is regarded as the resultant of the main reflection and a large number of "elementary" signals scattered by the ionosphere irregularities. The variations of the latter signals are of a random nature, and they characterize the degree of irregularity of the reflecting layer. Formulas are derived for determining the displacement velocity of the irregularities and the ratio of the energy of the main reflection to that of the scattered reflections. Results of experiments are given showing that reflection from the *F*<sub>2</sub> layer is nearly always of this statistical character.

551.510.535 131  
Comments concerning the Paper 'Fine Structure of the Lower Ionosphere' by R. A. Helliwell, A. J. Mallinckrodt, and F. W. Kruse, Jr.—R. J. Nertney. (*Jour. Geophys. Res.*, vol. 56, pp. 449-451; September, 1951.) From the results of an extensive series of group-height, absorption, polarization, and phase-height measurements on a frequency of 150 kc, a model of the lower ionosphere has been developed which appears to satisfy the theoretical and experimental results on a diurnal and seasonal basis at this frequency. Another interpretation is suggested for the two apparent "reflection" heights noted by Helliwell et al. (1898 of 1951).

551.510.535 132  
The D-Layer of the Ionosphere—A. P. Mitra. (*Jour. Geophys. Res.*, vol. 56, pp. 373-402; September, 1951.) A résumé is given of the present state of knowledge of the *D* region, both theoretical and experimental work being summarized. New theoretical studies of the formation and structure of the *D* region are made, based on contemporary knowledge. It is assumed that the *D* region is produced by ionization of O<sub>2</sub> at the first ionization potential. The densities of electrons and ions are calculated for various heights, taking account of the variation of atmospheric temperature and recombination coefficient with height. The distribution does not follow a Chapman law. The electron density increases continuously with height, although the ion density has a maximum value at nearly the same height as the rate of ion production, as in the Chapman distribution. The variation of height of the reflecting layer with solar zenith angle for long and very long waves is explained, and satisfactory agreement is obtained between experimental measurements of reflection coefficient at low frequencies and values derived from the theory.

551.510.535 133  
A Note on Certain Characteristics of the Normal E-Layer—C. H. Grace. (*Jour. Geophys. Res.*, vol. 56, pp. 452-454; September, 1951.) A method due to Kelso was used in converting *E*-region equivalent heights, measured at Pennsylvania State College, to true heights. The true height of maximum ionization, *h*<sub>m</sub>, was found not to follow Chapman theory except for an hour after sunrise and an hour before sunset. During most of the day, *h*<sub>m</sub> was relatively constant at about 115 to 120 km. For a period centered on noon, the effective recombination coefficient varies with height, in the range 108 to 120 km, in a manner suggestive of pressure dependence.

551.510.535:523.75 134  
Ionospheric Effects of Solar Flares—M. A. Ellison. (*Mon. Not. R. Astr. Soc.*, vol. 110, p. 626; 1950.) Summary of paper in *Publications of the Royal Observatory, Edinburgh*, vol. 1, no. 4, 1950. Five types of sudden ionospheric disturbances, noted during 1949 from continuous radio and magnetic records, were studied in relation to flare outbursts as seen simultaneously by *H*<sub>α</sub> light in the spectrohelioscope. The effects on the *D* layer are confined to the illuminated hemisphere, and are independent of the location of the flare on the sun's disk, showing the operative radiation to be ultraviolet light. The flares may accelerate cosmic-ray particles, and these may contribute to the ionization towards the end of the disturbances.

551.510.535:621.396.11 135  
Lateral Deflection of the Ray on Reflection at an Inhomogeneous Ionosphere Layer—Rawer. (See 244.)

551.510.535:621.396.11.029.51 136  
Effects of Ionosphere Disturbances on Low Frequency Propagation—Watts and Brown. (See 246.)

551.510.535:621.396.11.029.51 137

**A Method for Obtaining the Wave Solutions of Ionospherically Reflected Long Waves, Including all Variables and their Height Variation**—J. J. Gibbons and R. J. Nertney. (*Jour. Geophys. Res.*, vol. 56, pp. 355–371; September, 1951.) A method of solution is given for the one-dimensional wave equation  $\pi''/\pi = -\kappa_0^2 \epsilon^2(x)$  which arises in the application of wave theory to the study of the ionosphere. The method is applied to the problem of reflection from the *E* layer at 150 kc, Chapman distributions with various maximum electron densities being assumed. A brief comparison with experimental observations indicates that the calculated absorption is too low. This supports the theory of a *D* region below the *E* layer. The phase heights are fairly consistent with measured group heights, the sense of the difference agreeing with ionospheric dispersion theory.

LOCATION AND AIDS TO NAVIGATION 621.396.93 138

**Radio Direction Finding from the Morphological Viewpoint**—W. Stanner. (*Elektron Wiss. Tech.*, vol. 5, pp. 135–176; May, 1951.) A comprehensive review of the subject dealing with (a) arrangements for directional reception of medium, long, and ultra-short waves, (b) arrangements for directional transmission, (c) the consol system, (d) various methods of distance measurements, (e) radar equipment, (f) anti-radar methods, (g) geophysical and astrophysical problems of radio df.

621.396.93 139

**'Telegon' Direction Finder**—W. Runge, M. Strohacker, and A. Troost. (*Telefunken Ztg.*, vol. 24, pp. 75–81; June, 1951.) Description of Telefunken equipment for ships, with a wavelength range of 85 to 1,530 m. Circular crossed coils 110 cm in diameter, together with a vertical rod 2.6 m long and coincident with the common diameter of the coils, constitute the antenna system. The special features of the Type-E374N receiver are described, and a simplified circuit diagram is given. The total frequency range is covered in four ranges with adequate overlap. For an account of the goniometer used, see 140 below (Troost and Jankovsky).

621.396.93 140

**Recent Goniometer Developments**—A. Troost and R. Jankovsky. (*Telefunken Ztg.*, vol. 24, pp. 81–85; June, 1951.) Improvements in goniometer design resulting from the use of iron-cored rotors, iron rings, and shields, are reviewed, and a description is given of the goniometer used in the Telegon receiver Type-E374N (139 above). This is of the iron-shielded type with a high- $\mu$  rotor core which gives the requisite inductance of the windings with a relatively small number of turns. The residual bearing error is  $<0.15^\circ$ . Methods of test are outlined.

621.396.93.029.62 141

**Ultra-Short-Wave Direction-Finding Installation PV-1B (Direction-Finding Installation at Kloten Airport)**—W. Schoeberlein. (*Bull. schweiz. elektrotech. Ver.*, vol. 42, pp. 226–232; April 7, 1951. In German.) Outline of the principles of operation and features of the single-receiver automatic system in operation since 1949 [see 1078 of 1949 (Cleave)]. Sources of error in the Adcock fixed-antenna system are briefly discussed. Remote indication introduces an error of not more than 1 per cent.

621.396.93.088 142

**Polarization Errors of Radio Direction Finders, a Proposed Classification**—P. G. Hansel. (*PROC. I.R.E.*, vol. 39, p. 970; August, 1951.) "Primary instrumental polarization errors" are defined to be those which arise when the response of the antenna system to an "unwanted" primary component of the received wave is large. "Secondary polarization errors"

are those which arise when the antenna does not respond to the primary "unwanted" component, but takes a bearing on reradiated waves polarized in the "wanted" direction.

621.396.93.089.6 143

**The Calibration of Aircraft Direction Finders with Particular Reference to Site Selection**—J. H. Moon. (*Marconi Rev.*, vol. 15, pp. 101–112; 3rd Quarter, 1951.) Experiments are described which show that radio waves are refracted as they pass over reinforced-concrete runways. Errors were observed on a loop direction finder at frequencies between 200 and 700 kc, with waves incident horizontally at an angle of  $50^\circ$  to the line of the runway. The maximum error was about  $6^\circ$  at the edge of the runway and  $1.5^\circ$  at a distance of 100 feet from it.

621.396.933 144

**A Straight-Line-Flight Indicator for the Pilot of a Radar-Equipped Aircraft**—R. C. Richardson. (*Aust. Jour. Appl. Sci.*, vol. 2, pp. 223–234; June, 1951.) An attachment to shoran airborne equipment to assist the pilot in flying along any predetermined straight-line path. Ranges from the ground beacons are transmitted mechanically from the shoran oscillograph to the aircraft equipment. There they are used to set the position of a probe moving parallel to a glass plate coated with a thin layer of metal through which lines, which represent the desired flight paths, are engraved. Divergence of the flight from one of these lines is indicated to the pilot by a center-zero meter. In trials the pilot was able to control the aircraft so that its average departure from a straight-line path was about  $\pm 0.02$  mile.

621.396.933 145

**Modern Radar Landing Systems**—M. Sollima. (*HF* (Brussels), no. 10, pp. 270–286; 1951.) The principles and practice of G.C.A. are described and exemplified by the C.F.T.H. installation at Melsbroeck-lez-Bruxelles airport. This uses a precision radar equipment working on a frequency of 9,375 mc with a peak power of 35 kw. The antennas give a horizontal beam  $3.5^\circ$  wide and  $0.6^\circ$  deep for determination of angular elevation, and a vertical beam of width  $0.6^\circ$  and depth  $2^\circ$  for determination of bearing, the energy in secondary lobes being less than 5 per cent of that in the principal lobe. The construction of the variable-width waveguides to secure fine scanning is described, together with ancillary apparatus.

621.396.933 146

**Blind-Landing System Type A. B.**—A. Moisson. (*Rev. Tech. Comp. franç. Thomson-Houston*, no. 15, pp. 5–18; April, 1951.) A detailed description of the equipment. See also 145 above (Sollima).

621.396.932/.933.24 147

**Radio Beacon 'Sol'**—M. Borondo. (*Rev. Telecommun.* (Madrid), vol. 6, pp. 23–25; December, 1950.) Short description and theory of the consol system. See also 2912 of 1946 (Clegg) and 2252 of 1948 (Jessell).

#### MATERIALS AND SUBSIDIARY TECHNIQUES

535.215:546.431-31 148

**Optical Absorption and Photoconductivity in Barium Oxide**—W. W. Tyler and R. L. Sproull. (*Phys. Rev.*, vol. 83, pp. 548–555; August 1, 1951.) "Measurements of the optical absorption and photoconductivity in BaO single crystals are reported. The threshold photon energy for both processes is 3.8 ev, and the absorption constant at higher energies is at least  $10^5 \text{ cm}^{-1}$ . A second increase in the absorption constant begins at about 4.8 ev, and is not accompanied by photoconductivity. The observed dependence of photoconductivity on temperature and electric field strength indicates space charge effects in limiting current flow. The onset of absorption at 3.8 ev is

thought to be due to the production of excitons, with the accompanying photoconductivity due to thermal dissociation of excitons or exciton ionization of impurity centers."

535.215:546.431-31 149

**Photoconductivity and Photoelectric Emission of Barium Oxide**—H. B. DeVore and J. W. Dewdney. (*Phys. Rev.*, vol. 83, pp. 805–811; August 15, 1951.) Measurements were made on sprayed coatings of BaO on Ni. The variation of the characteristics with temperature and during activation is shown in diagrams. The results are discussed with reference to energy levels.

535.215 + 535.37]:546.472.21 150

**A Comparative Study of Photoconductivity and Luminescence**—R. H. Bube. (*Phys. Rev.*, vol. 83, pp. 393–396; July 15, 1951.) Measurements are reported of the luminescence and photoconductivity of ZnS as functions of (a) operating temperature during excitation, (b) time, and (c) temperature during thermostimulation. The results are discussed. They indicate different mechanisms for the two processes.

535.215 + 535.37]:546.482.21 151

**Electron Mobility and Luminescence Efficiency in Cadmium Sulfide**—L. Gildart and A. W. Ewald. (*Phys. Rev.*, vol. 83, pp. 359–363; July 15, 1951.)

535.37 152

**Electron Penetration and Scattering in Phosphors**—L. R. Koller and E. D. Alden. (*Phys. Rev.*, vol. 83, pp. 684–685; August 1, 1951.) ZnS films ranging in thickness from 0.1 to  $0.45 \mu$  were deposited on glass and were irradiated at a constant current density of  $0.8 \mu \text{ A/cm}^2$ . The luminescence brightness was measured as a function of beam voltage, using a photomultiplier with cathode ray tube display. The results show that nearly 90 per cent of the beam energy is lost in a distance of half the range of the electrons.

535.37 153

**Properties of a  $\text{CaSO}_4\text{-Mn}$  Phosphor under Vacuum Ultraviolet Excitation**—K. Watanabe. (*Phys. Rev.*, vol. 83, pp. 785–791; August 15, 1951.) An investigation of the long-period phosphorescence excited by wavelengths below  $1,350 \text{ \AA}$ .

535.37:537.39:546.281.26 154

**Injected Light Emission of Silicon Carbide Crystals**—K. Lehovc, C. A. Accardo, and E. Jamgochian. (*Phys. Rev.*, vol. 83, pp. 603–607; August 1, 1951.) The yellow light emitted by certain SiC crystals was investigated as a function of temperature and of current through the crystal. The light intensity varies approximately linearly with current, and experiments under pulsed conditions indicate good hf response. The emission spectrum changes considerably with temperature, but only slightly with current density. The mechanism of the light emission is discussed and attributed to the recombination of carriers injected through *p-n* boundaries. This process is contrasted with emission from phosphors under bombardment.

537.226 155

**The Origin of Ferroelectricity**—G. A. Smolenski and N. V. Kozhevnikova. (*Compt. Rend. Acad. Sci. (URSS)*, vol. 76, pp. 519–522; February 1, 1951. In Russian.) The deciding factor for the appearance of ferroelectricity is a certain mutual disposition of oxygen octahedra in the crystal. A table of all known substances which exhibit this effect, and of substances in which this effect can be expected at certain temperatures, is included.

537.226 156

**Domain Boundary Motion in Ferroelectric Crystals and the Dielectric Constant at High Frequency**—C. Kittel. (*Phys. Rev.*, vol. 83, p. 458; July 15, 1951.)

- 537.226.1:546.431-31 157  
The Dielectric Constant of Barium Oxide—R. S. Bever and R. L. Sproull. (*Phys. Rev.*, vol. 83, pp. 801-805; August 15, 1951.) Measurements were made on BaO crystals for the frequency range 60 cps to 60 mc and temperature range  $-25^{\circ}$  to  $+60^{\circ}\text{C}$ . The value found for the dielectric constant in these ranges was about 34, rising at the lowest frequencies.
- 537.311.33 158  
Volume Rectification in Zincite—S. R. Khastgir, S. K. R. Tolpadi, and S. C. Mitra. (*Nature* (London), vol. 168, pp. 162-163; July 28, 1951.) Experiments are reported which indicate that the rectification in zincite depends on the volume and not on the area in contact with the electrodes. A theoretical explanation based on the crystal structure is given.
- 537.311.33 159  
Semiconductors—R. L. Ortuetta and E. Y. Garrido. (*Rev. Telecomun.* (Madrid), vol. 6, pp. 12-22; December, 1950.) A concise account of the properties of semiconductors, with theory based on energy-level bands. A table and diagrams give the physical constants and rectification characteristics of Ge.
- 537.311.33 160  
The Electrical Conductivity of Simple p-Type Semiconductors—A. Lempicki. (*Proc. Phys. Soc.*, vol. 64, pp. 589-590; June 1, 1951.) An analysis is outlined, which establishes a complete analogy between electron and hole conduction. In both cases conductivity passes through a maximum with increasing temperature.
- 537.311.33 161  
A Study of Thermoelectric Effects at the Surfaces of Transistor Materials—J. W. Granville and C. A. Hogarth. (*Proc. Phys. Soc.*, vol. 64, pp. 488-494; June 1, 1951.) The surfaces of various specimens of Ge and PbS have been explored with a whisker contact, and the character of the conduction mechanism in relatively small regions has been examined by the polarity of (a) the photo-voltaic effect, (b) the rectification, and (c) the thermoelectric effect. Methods (a) and (b) give results characteristic of the bulk material as determined by Hall effect measurements, whereas method (c) only gives results consistent with (a) and (b) for uncontaminated cleaved surfaces or for surfaces which have been etched after polishing. For polished surfaces, anomalous effects are obtained and point to the existence of a layer on the surface of character different from that of the bulk semiconductor.
- 537.311.33:538.221 162  
On the Dispersion of Resistivity and Dielectric Constant of Some Semiconductors at Audiofrequencies—C. G. Koops. (*Phys. Rev.*, vol. 83, pp. 121-124; July 1, 1951.) Semiconducting Ni/Zn ferrites were investigated. A simple model, comprising highly conductive grains separated by layers of lower conductivity, is proposed to explain the dispersion of ac resistivity and apparent dielectric constant. Dispersion formulas are given. The theory is supported by experimental results.
- 537.311.33:546.289 163  
The Effect of Fast Neutron Bombardment on the Electrical Properties of Germanium—J. W. Cleland, J. H. Crawford, Jr., K. Lark-Horovitz, J. C. Pigg, and F. W. Young, Jr. (*Phys. Rev.*, vol. 83, pp. 312-319; July 15, 1951.) The effect of lattice disorders introduced by bombardment is discussed from the theoretical standpoint, and measurements are reported. For *n*-type Ge, the conductivity under bombardment first decreases and then increases; on passage through the minimum, the material is converted to *p*-type. The conductivity of *p*-type material increases under bombardment, tending towards a saturation value. Figures are quoted for the rate per neutron of carrier removal and introduction in *n*- and *p*-type Ge, respectively. Related temperature effects are described. A footnote mentions that for both *n*- and *p*-type Si, bombardment produces only a decrease of conductivity.
- 537.311.33:546.289 164  
Observations of Zener Current in Germanium *p-n* Junctions—K. B. McAfee, E. J. Ryder, W. Shockley, and M. Sparks. (*Phys. Rev.*, vol. 83, pp. 650-651; August 1, 1951.) Junctions in a Ge single crystal were examined using As as the donor impurity and Ga as the acceptor. The reverse I/V characteristic was measured over a 5-decade range of current, and the critical voltage gradient across the junction was studied by observing the variation of capacitance of the junction with reverse voltage. While the slope of the characteristic in the high-current part of the range agrees well with theory, the critical voltage-gradient predicted is about three times the measured value.
- 537.312.6:621.315.592† 165  
Investigation of Semiconductors at High Temperatures, Refractory Thermistors—N'Guyen Thien-Chi and J. Suchet. (*Ann. Radioélect.*, vol. 6, pp. 99-105; April, 1951.) The materials investigated included the normal refractory oxides, MgO, SiO<sub>2</sub>, ZrO<sub>2</sub>, etc., and mixtures of these with such metals as Ni, Co, Fe, etc., and the semiconducting oxides of Zn, Ti, Ta, and V. The work has resulted in the commercial production of a wide range of stable, robust thermistors for use at 250 to 300°C, possessing high temperature coefficients (5.5 per cent/°C), and of refractory thermistors operating up to 1,100°C, giving much better control than is obtainable with thermocouples or the usual resistive probes.
- 537.312.8:546.289 166  
The Magnetoresistance Effect in Oriented Single Crystals of Germanium—G. L. Pearson and H. Suhl. (*Phys. Rev.*, vol. 83, pp. 768-776; August 15, 1951.) An extensive experimental study of the effect as a function of the orientation of magnetic field and electric current relative to the crystal axes. "The measurements are internally consistent with existing phenomenological theory based on cubic crystal symmetry, in which terms involving the magnetic field to higher than the second order are neglected. It is shown that such deviations as do occur arise from higher terms in the field, since an extension of the phenomenological theory to the fourth order predicts their symmetry. Relations are established between the experimentally observed phenomenological constants and those constants appearing in existing magnetoresistance electronic theories."
- 538.221 167  
On Ferromagnetic States—J. Giltay. (*Appl. Sci. Res.*, vol. B2, no. 3, pp. 199-216; 1951.) Reprint. See 126 of 1951.
- 538.221 168  
Structure and Properties of Ferrites—F. G. Brockman. (*Elec. Eng.*, vol. 70, pp. 489-494; June, 1951.) 1951 AIEE Winter General Meeting paper. Advances in the understanding of ferromagnetic ferrites subsequent to those reported in 660 of 1950 are reviewed. Particular attention is paid to Néel's theory.
- 538.221:[534.321.9:534.373 169  
The Influence of Magnetization on Ultrasonic Attenuation in a Single Crystal of Nickel or Iron-Silicon—S. Levy and R. Truett. (*Phys. Rev.*, vol. 83, pp. 668-669; August 1, 1951.) Report of measurements made using ultrasonic beams of frequency 5 to 50 mc, with constant magnetic fields, of intensities ranging from zero to saturating field, applied both perpendicular to and parallel to the beam direction. At saturation the beam attenuation is low and constant over the frequency range.
- 538.632:621.315.592† 170  
Resistivity and Hall Constant of Semiconductors—C. N. Klahr. (*Phys. Rev.*, vol. 83, p. 460; July 15, 1951.) Correction to paper noted in 2206 of 1951.
- 539.23:546.26:537.311.32 171  
The Conductivity of Thin Carbon Films—A. Blanc-Lapierre, M. Perrot, and N. Nifontoff. (*Compt. Rend. Acad. Sci. (Paris)*, vol. 233, pp. 141-143; July 9, 1951.) Nonlinear films of resistance 1 to 50 meg $\Omega$  have been found by Perrot and Lavergne to have different resistance properties over different ranges of values of applied voltage. An experimental investigation of carbon films of resistance  $<0.5$  meg $\Omega$  is reported here which extends the range of the earlier findings. Voltages of 1 to 40 v were used. Results are shown as families of log R/log I curves. Formulas for the various ranges are developed, and values derived for various parameters are tabulated.
- 539.23:546.59 172  
Influence of the Support on the Crystallization of Very Thin Gold Films—A. Colombani and G. Ranc. (*Compt. Rend. Acad. Sci. (Paris)*, vol. 233, pp. 46-48; July 2, 1951.) Continuation of experimental investigation noted in 2739 of 1951. Support materials studied include KCl, KBr, NaNO<sub>3</sub>, NaCl, rhodoid, plexiglas, and glass.
- 546.431.824 173  
The Lorentz Correction in Hexagonal Barium Titanate—J. R. Tessman. (*Phys. Rev.*, vol. 83, pp. 677-678; August 1, 1951.) An explanation based on the structure is advanced for the experimentally observed absence of ferroelectricity in the hexagonal modification of BaTiO<sub>3</sub>. See also 2188 of 1950 (Slater).
- 548.52:546.431-31 174  
Growth and Manipulation of Barium Oxide Crystals—R. L. Sproull, W. C. Dash, W. W. Tyler, and A. R. Moore. (*Rev. Sci. Instr.*, vol. 22, pp. 410-414; June, 1951.)
- 549.514.51:621.396.611.21.002.2 175  
Manufacture of Quartz Piezoelectric Crystals—G. Flórez. (*Rev. Telecomun.* (Madrid), vol. 6, pp. 3-22; June, 1951.) A detailed account of all processes from the initial examination of the raw material and determination of the optic axis up to the deposition of electrode material on the faces of crystal plates and their subsequent mounting.
- 620.197 176  
Some Principles and Practices in Tropicalisation—G. A. Durance, W. J. D. Harrison, and R. T. Lovelock. (*GEC Technol.*, vol. 4, pp. 23-32; 1949.) An account of the adverse effects of various climatic conditions on telecommunications apparatus, and of the means of overcoming them by impregnation, metal coating, the use of sealed components, etc. The importance of suitable mechanical design is stressed.
- 621.315.61 177  
Dielectric Properties of Insulators—K. W. Wagner. (*Alta Frequenza*, vol. 20, pp. 3-27 and 68-79; February and April, 1951.) Theories regarding the relation of the dielectric properties to the structure of the material are reviewed. The influence of temperature and humidity is examined. The effects of drying and impregnation on paper are investigated.
- 666.1.037 178  
A Method of Sealing Sapphire to Glass—H. Rawson. (*Jour. Sci. Instr.*, vol. 28, pp. 208-209; July, 1951.) A modification of the method given in 179 below is described, using hf induction heating.
- 661.1.037:621.383 179  
A Method of Sealing Sapphire to Glass and its Application to Infra-red Photocells—R. P. Chasmar, J. L. Craston, G. Isaacs, and A. S. Young. (*Jour. Sci. Instr.*, vol. 28, pp. 206-207; July, 1951.) The requirements of window mate-

rials for PbTe cells are discussed; artificially grown sapphire is both suitable and readily available. In the sealing method described, the glass is heated to a high temperature so that it wets the sapphire.

**533.5** **180**  
**La Technique du Vide [Book Review]**—M. Leblanc. Publishers: Armand Colin, 188 pp. (*Bull. Soc. franç. élect.*, vol. 1, p. 252; May, 1951.) "... this little treatise will be useful to all those... who are interested in vacuum technology."

**621.315.616:058.2** **181**  
**Modern Plastics Encyclopedia and Engineer's Handbook, 1951 [Book Notice]**—Publishers: Plastics Catalogue Corporation, New York, N. Y., 15th edn, 636 pp. A record of developments in plastic materials, machinery, engineering, techniques and applications, with a special section, "Plastics in Defense," giving information on applications of plastics by the U.S. Services and related government bureaus, and on the location of the relevant government offices. The directory section lists all U.S. manufacturers of plastic materials, machinery, and equipment.

### MATHEMATICS

**51.537.315.6** **182**  
**Mathematical Tools for the Solution of Problems of the Distribution of Potential**—J. J. R. Moral. (*Rev. Telecomun.* (Madrid), vol. 6, pp. 38-41; June, 1951.) In many cases such problems are most conveniently dealt with in cylindrical or spherical co-ordinates. Laplace's equation is transformed to spherical co-ordinates, and a solution is obtained in terms of Legendre functions.

**512.831:621.392.5** **183**  
**Transformation of the Quadripole-Network Matrix to the Diagonal Form**—Schulz. (*See* 68.)

**681.142** **184**  
**The New Universal Digital Computing Machine at the University of Manchester**—T. Kilburn. (*Nature* (London), vol. 168, pp. 95-96; July 21, 1951.) Detailed description of a machine recently put into service, incorporating improvements over the experimental model described in 133 of 1950.

### MEASUREMENTS AND TEST GEAR

**537.54:621.396.822** **185**  
**Gaseous Discharge Super-High-Frequency Noise Sources**—H. Johnson and K. R. De Remer. (*Proc. I.R.E.*, vol. 39, pp. 908-914; August, 1951.) The positive column of a discharge in argon provides a standard noise source at microwave frequencies, the noise temperature being about 15.5 db above 290°K. The discharge tube is inserted diagonally across a waveguide, a good termination being obtained without using tuned elements. Performance data are given for the frequency band 2.6 to 26 kmc. The effects of varying the discharge parameters are discussed.

**621.3.011.2(083.74):621.315.212** **186**  
**Coaxial Impedance Standards**—R. A. Kempf. (*Bell Sys. Tech. Jour.*, vol. 30, pp. 689-705; July, 1951.) "The calibrations of bridge networks used in developmental tests on coaxial cable are obtained by comparison of the networks with calculable standards of impedance consisting of a group of short-length precision copper coaxial lines. The standards are calculable by reason of the availability of precise formulas relating the distributed primary constants to the measurable physical constants and dimensions of the co-axials. This paper outlines the constructional problems and design features of a group of such standards of impedance which provide a range of values over a broad band of frequencies."

**621.317.3:621.314.6** **187**  
**Measurement of the Temperature De-**

pendence of the Voltage Drop and of the Backward Current in Dry Rectifiers. Measurement Methods and Apparatus—K. Maier. (*Arch. tech. Messen.*, no. 185, pp. T71-T72; June, 1951.) Measurements of the static characteristic are carried out with direct voltage, but most other measurements with pulsed steady direct voltage. A method for the simultaneous measurement of the dynamic forward and backward currents is described.

**621.317.3:621.396.615.029.3+534.232** **188**  
**The Generation of Audio-Frequency Voltages for Measurement Purposes**—O. Schmid. (*Funk u. Ton*, vol. 5, pp. 133-142; March, 1951.) General description of the principles of different types of tone source, including electro-mechanical devices and, particularly, self-excited oscillators. Basic circuits are shown for the RC-, glow-discharge-tube- and heterodyne-type generators. Their features and advantages are discussed. For high precision, tuning-fork or quartz generators are required.

**621.317.3:621.396.822** **189**  
**The Measurement of Fluctuation Noise by Diode and Anode-Bend Voltmeters**—R. E. Burgess. (*Proc. Phys. Soc.*, vol. 64, pp. 508-518; June 1, 1951.) "The response of a diode voltmeter to a cw sine-wave signal, and to noise, is analyzed for three typical diode characteristics: discontinuous linear, discontinuous parabolic, and exponential. In the first type, the indication is proportional to the rms value of the input voltage, but the constant of proportionality is different for noise and for cw, and depends upon the ratio of the load resistance to diode resistance. For small input signals, the curvature of the diode characteristic is important, and the voltmeter tends to a square-law behavior, with the result that cw, noise or a mixture of cw, and noise, can all be measured in terms of a single calibration. The input conductance of a diode voltmeter is, in general, greater for noise than for cw. It can be very much greater in practical conditions, and this represents a possible source of error in the measurement of noise. The response of the anode-bend voltmeter to cw and to noise is considered for a discontinuous parabolic and for an exponential characteristic. The departure of the cw calibration from a square law, and the difference between cw and noise calibrations, are evaluated in terms of the characteristics."

**621.317.318.087:621.395.625.3** **190**  
**Magnetic-Tape Recording of Electrostatic Field Changes**—N. D. Clarence and D. J. Malan. (*Proc. Phys. Soc.*, vol. 64, p. 529; June 1, 1951.) Brief description of a method of photographic recording which reduces film consumption.

**621.317.335.3.087.4†** **191**  
**Automatic Measurement Computation and Recording of Dielectric Constant and Loss Factor against Temperature**—E. B. Baker. (*Rev. Sci. Instr.*, vol. 22, pp. 376-383; June, 1951.) The terms  $\epsilon'$  and  $\epsilon''$  are recorded as a function of temperature from -23°C to +150°C, at given frequencies between 50 cps and 600 kc, for solids in the form of thin disks. A modified Schering bridge is used. Circuit details are given of the associated equipment.

**621.317.337.029.64†** **192**  
**Detection of Small Variations in the Quality Factors of a Cavity Resonator**—R. Malvano and M. Panetti. (*Alta Frequenza*, vol. 19, pp. 231-243; October-December, 1950.) Description and analysis of a dynamic method in which an FM signal is applied to the cavity input. A crystal detector circuit in the output is used to measure the relative variations in output voltage. These are proportional to  $\Delta Q/Q$ . Errors introduced by the generator and detector are negligible. An example is given of the application of the method in investigation of the absorption spectra of paramagnetic substances.

**621.317.35** **193**  
**Harmonic Analysis of a Distorted Oscillation after Amplitude Limiting**—M. Kolscher. (*Arch. elekt. Übertragung*, vol. 5, pp. 293-299; June, 1951.) In FM oscillations, distortion can be reduced by amplitude limiting. For the case of a sinusoidal interfering oscillation, this effect has hitherto only been investigated theoretically under particular assumptions concerning the frequency ratio and amplitude ratio of the main and interfering oscillations, and the shape of the limiter characteristic. The dependence of the results on the frequency ratio is here made clear, and a new method of analysis is developed which is applicable for all amplitude ratios and characteristics. Numerical calculations for a typical case show what limiter characteristics give the best interference elimination, and what characteristics can be used without the interference becoming appreciably greater.

**621.383.27†:621.317.42** **194**  
**Investigation of the Conditions for Use of Kubetski's Mosaic Multiplier as an Indicator of the Magnetic Field**—Krasnogorskaya. (*See* 298.)

**621.317.42:621.385.833** **195**  
**Inductance Method for studying the Field Pattern on the Axis of a High-Power Magnetic Electron Lens**—C. Fert and P. Gautier. (*Compt. Rend. Acad. Sci. (Paris)*, vol. 233, pp. 148-150; July 9, 1951.)

**621.317.43** **196**  
**Measurements on Coils with Iron Cores at Frequencies between 1 c/s and 1 mc/s**—H. Wilde. (*Arch. tech. Messen.*, no. 183, pp. T39-T40; April, 1951.) Three factors of which account should be taken are hysteresis, magnetic after-effect, and eddy currents. Effective means described for determining these are, respectively: permeability measurement at very low frequencies using a type of mutual-inductance bridge to eliminate the effect of copper losses; extrapolation to zero field strength of the inductance characteristic measured by a Maxwell-Wien bridge; a similar procedure carried out at high frequency using a capacitance-tuned resonance bridge, or one with a folded-slide-wire balancing element.

**621.317.44** **197**  
**Principles of the Design of Pulse-Transformer Laminations: Pulse Hysteresis Meter**—P. Bouvier and B. Daugny. (*Rev. tech. Comp. franç. Thomson-Houston*, no. 15, pp. 51-67; April, 1951.) A hysteresis meter is described for use in investigating the properties of magnetic cores under operating conditions such as obtain in the pulse transformers used in radar equipment. It consists of a modulating unit of peak power 1 MW producing a 0.5- $\mu$ s pulse across the terminals of a winding on the core tested, and a measurement unit enabling the shape of the voltage pulse, the magnetic field, the magnetic induction, and the hysteresis loop to be obtained.

**621.317.7** **198**  
**Sensitivity of Electrical Measurement Apparatus and its Enhancement**—F. Moeller. (*Arch. tech. Messen.*, no. 185, p. T68; June, 1951.)

**621.317.7:537.312.6:621.315.592†** **199**  
**The Use of Thermistors for Temperature Compensation in Precision Measurement Apparatus**—N'Guyen Thien-Chi and J. Suchet. (*Ann. Radioélect.*, vol. 6, pp. 106-108; April, 1951.) The increase of resistance with temperature of the copper coils of electrical measuring apparatus may be compensated by the use in series or in parallel of thermistors possessing negative temperature coefficients.

**621.317.7:621.396.619.2** **200**  
**A New Modulation Meter**—H. Müller. (*Telefunken Ztg.*, vol. 24, pp. 55-60; March,

1951.) A meter suitable for monitoring the modulation of broadcasting transmitters and magnetic-tape, disk, or sound-film equipment is described. The amplitude range is  $-45$  db to  $+5$  db, with an approximately uniform logarithmic scale, and the frequency range is 40 to 15,000 cps. A separate indicating instrument is provided in addition to that in the apparatus. Calibration at 0, 1, and 100 per cent modulation is effected by stabilized voltages derived from the supply unit.

621.317.7.085.34:621.383 201  
Some Points in the Design of Optical Levers and Amplifiers—R. V. Jones. (*Proc. Phys. Soc.*, vol. 64, pp. 469–482; June 1, 1951.) Sources of instability in optical levers using photoelectric amplifiers are discussed, and the design of a high-precision instrument is described.

621.317.7.088.6 202  
Compensation of A.C. Instruments for Variations in Frequency—J. H. Miller. (*Elec. Eng.*, vol. 70, pp. 494–497; June, 1951.) 1951 AIEE Winter General Meeting paper. A general solution is presented for compensation over the frequency range up to 5 kc. The series resistance of the meter is shunted by a capacitor whose value is rigorously calculated.

621.317.727.088 203  
Leakage, Stray Capacitance and Inductance in Potentiometer Comparison Measurements with Direct and Alternating Currents—J. H. Gosselin. (*Rev. gén. élect.*, vol. 60, pp. 244–253; June, 1951.) The effects of insulation faults in dc potentiometers are examined. These arise notably in the auxiliary circuit connections, and can be reduced by suitably locating the galvanometer and switch. In ac potentiometers, stray capacitance gives rise to leakage currents in quadrature with inter-circuit voltages, and inductance effects due to ambient magnetic fields are also significant. Compensation methods are described for reducing relative errors resulting from these effects to the order of  $10^{-6}$ .

621.317.733:621.317.382 204  
A Self-Balancing Microwave Power Measuring Bridge—L. A. Rosenthal and J. L. Potter. (*Proc. I.R.E.*, vol. 39, pp. 927–931; August, 1951.) 1950 URSI-IRE Meeting paper. "The basic techniques of microwave power measurement are discussed, together with principles of self-balancing bridges for that application. A method of measuring the power change by means of a nonlinear "slave" bridge is presented. Temperature compensation problems as applied to the meter under consideration are discussed. The complete power meter is considered along with operating procedure."

621.317.733.011.21† 205  
Impedance Measurement Bridge for Determination of Aerial Impedances in the Medium-Wave Band—K. Fischer. (*Elektrotech. u. Maschinenb.*, vol. 68, pp. 249–252; May 15, 1951.) The instrument is designed particularly for measurement of impedance in which the reactive component is large, the resistive component being balanced by capacitive tuning. Particular attention is paid to screening and compensation of stray capacitances. Tuning reactors are contained in a separate screened unit. The bridge is fed from a tone-modulated hf source enabling an aural-null indication of balance to be used.

621.317.733.011.3/4 206  
An Easily Operated Precision Measurement Bridge for Self-Inductors and Capacitors with Losses—E. Sorg. (*Funk u. Ton*, vol. 5, pp. 202–209; April, 1951.)

621.317.733.025:621.385.832 207  
The C. R. Tube as Indicator for A. C. Bridges—R. Oetker. (*Frequenz*, vol. 5, pp. 33–38; February, 1951.) Conditions are investigated for the use of cathode ray tubes as indi-

cators of complex variables in familiar bridge circuits. Particular attention is given to sources of error.

621.317.74:621.397.5 208  
Transmission Measuring System—O. D. Engstrom. (*Bell Lab. Rec.*, vol. 29, pp. 264–268; June, 1951.) The apparatus measures phase distortion in the transmission of video signals along transmission lines. The calibrating signal consists of two sine waves with a constant frequency difference of 200 kc, the frequency range extending upwards to 3 mc. The phase shift of the resulting 200-kc envelope for any frequency pair is compared oscillographically with the phase of the envelope resulting from a standard frequency pair of 892 kc and 1,092 kc.

621.392.001.4 209  
Determination of Amplitude and Phase Characteristics of Linear Networks by means of Square Waves—J. Müller. (*Fernmeldelech. Z.*, vol. 4, pp. 211–220; May, 1951.) Detailed theory of the method is given. The construction of a square-wave generator for the range 50 cps to 6 mc is described, and also the method adopted for its calibration. The great advantage of the method is that the amplitude and phase characteristics of a network can be determined over a relatively wide band of network frequencies by means of a single square-wave test frequency. Auxiliary equipment comprises a wide-band cro with timebase circuit for a frequency of 1 mc and deflection proportional to time, and a wide-band amplifier. Examples of the application of the method include (a) anode circuit of an amplifier, (b) two-stage low-pass filter, (c) If transformer, (d) magnetophone, (e) band-pass filters. See also 210 below (Meyer-Eppler).

621.392.001.4 210  
Measurement of the Frequency Characteristics of Linear Systems by Single or Repeated Switching Processes—W. Meyer-Eppler. (*Fernmeldelech. Z.*, vol. 4, pp. 174–182; April, 1951.) Nonstationary methods of measurement are discussed, and methods using single pulses, periodic series of pulses, or square waves are described, particular reference being made to low-pass, high-pass, and band-pass filters, and resonators.

621.396.621.001.4 211  
Systematic Analysis of the Properties of Radio Receivers—Fromy. (See 252.)

621.397.6.001.4 212  
Traveling-Wave Amplifier Measurements—F. E. Radcliffe. (*Electronics*, vol. 24, pp. 110–111; August, 1951.) Circuits and procedures for transmission and impedance measurements on wide-band amplifiers are described. Frequency sweeps of 500 mc at 4 kmc with a repetition rate of 60 cps are used, and measurements are accurate to within 2 per cent.

621.317:621.314.6 213  
Gleichrichtermesstechnik (Rectifier Measurement Technique) [Book Review]—H. F. Grave. Publishers: Geest and Portig, Leipzig, Germany, 1950, 227 pp., 27 DM. (*Elektron Wiss. Tech.*, vol. 5, p. iv; April, 1951.) One of a series of monographs which deals with the general theory of different types of rectifier and their application in measurement circuits.

#### OTHER APPLICATIONS TO RADIO AND ELECTRONICS

621.316.578.1 214  
A Millisecond Timer—J. M. Sturtevant. (*Rev. Sci. Instr.*, vol. 22, pp. 359–362; June, 1951.) The circuits described produce a time delay of up to 10 seconds, accurate to within 1 ms, and can be used as a stop-clock reading to the same accuracy with manual or electrical control. A test pulse generator for adjustment purposes is also described.

621.365.54/.55† 215  
Fundamentals of High-Frequency Heating

—G. Lang. (*Bull. schweiz. elektrotech. Ver.*, vol. 42, pp. 289–303; May 5, 1951. In German.) After a short explanation of terminology and an historical review, the thermal aspect of the subject is discussed. The principle of induction heating is explained, and the importance of the depth of penetration is stressed. Dielectric heating is next considered. Different types of generator are reviewed, and their advantages and disadvantages for particular applications are noted.

621.365.54† 216  
Additions to the Generalized Theory of Power Transfer by Induction—M. van Lancker. (*Bull. Soc. franc. élect.*, vol. 1, pp. 241–251; May, 1951.) Further development of the theory published in 1950 (3112 of 1950), leading to a complete solution of the problem.

621.38.001.8 217  
A Judgment Box—W. H. Alexander. (*Electronic Eng.*, vol. 23, pp. 256–257; July, 1951.) Each factor influencing a decision which must be made is assigned a weight. By summation of voltages corresponding to the ten weighted factors, their weighted mean is shown on a meter.

621.38.001.8 218  
Electronic Protection for War Plants—R. Y. Atlee. (*Electronics*, vol. 24, pp. 96–101; August, 1951.) Photoelectric, capacitance, and acoustic alarm systems are discussed. Illustrations of recent installations, including boundary-protection systems, are given.

621.383.001.8 219  
Industrial Tristimulus Color Matcher—G. P. Bentley. (*Electronics*, vol. 24, pp. 102–103; August, 1951.) Construction and circuit details are given of a sensitive flicker-photometer instrument incorporating a photomultiplier.

621.384.6† 220  
The Yale Linear Electron Accelerator—H. L. Schultz and W. G. Wadey. (*Rev. Sci. Instr.*, vol. 22, pp. 383–388; June, 1951.) Design, construction, and performance of the accelerator are described. Independent cavity resonators driven by 500-kw triode power amplifiers are used, and large currents of 10-MeV electrons are produced.

621.384.6† 221  
Operation of a Six-MeV Linear Electron Accelerator—G. E. Becker and D. A. Caswell. (*Rev. Sci. Instr.*, vol. 22, pp. 402–405; June, 1951.) A traveling-wave type accelerator is described which uses a single magnetron as power source and operates at a wavelength of 10.5 cm, with a peak power output of 0.9 MW.

621.384.611† 222  
On the Radio-Frequency Requirements of High-Energy Electron Synchrotrons—T. R. Kaiser. (*Proc. Phys. Soc.*, vol. 64, pp. 502–507; June 1, 1951.) Taking into account the finite rate of rise, the required rf voltage for efficient transition from betatron to synchrotron operation is determined for two machines under construction.

621.384.612.2† 223  
The Synchrocyclotron at Amsterdam: Part 3—The Electromagnet—F. A. Heyn. (*Philips Tech. Rev.*, vol. 12, pp. 349–364; June, 1951.) Design, construction, and performance of the magnet are described. A method has been found for stabilizing the particle orbits. As a result, 28-MeV deuterons can be produced instead of the planned 25-MeV deuterons. Parts 1 & 2: 2790 of 1951.

621.385.38.001.8 224  
Measurement of Ignition Delay in Internal-Combustion Engines—J. Kwasieboriski. (*HF* (Brussels), no. 10, pp. 287–292; 1951.) Two thyatron, fired by impulses derived from the phenomena investigated, control the

functioning of a pentode the anode current of which is measured.

621.385.38.001.8 225  
A Simple Photostimulator—R. G. Bickford and W. T. Moffet. (*Electroencephalography clin. Neurophys.*, vol. 3, pp. 251–252; May, 1951.) A pulse generator using a thyratron triggers a flash tube, giving 0.5 to 50 flashes per second. Constructional component and details are given.

621.385.833 226  
German Society for Electron Microscopy: Third Annual Conference—(*Nature* (London), vol. 168, pp. 70–71; July 14, 1951.) Brief report of conference held on May 18 to 20, 1951 in Hamburg, at which about eighty papers dealing with the electronoptics and applications of electron microscopes were presented.

621.385.833 227  
On the Dioptrics of Electrostatic Electron Lenses—G. Wendt. (*Z. angew. Phys.*, vol. 3, pp. 219–225; June, 1951.) By inversion of the function expressing the potential distribution on the axis of the lens, characteristic relations are derived for the electron paths in basic types of accelerating lens and in the three-element independent lens. Substitution of axis potential for axial co-ordinate in the differential equation for the paraxial rays gives an equation of the Heun type with polynomial coefficients, the solutions of which are Riemann functions of second order with four branch points. For a similar method see *Compt. Rend. Acad. Sci.* (Paris), vol. 230, pp. 734–735; February 20, 1950. (Régenstreif.)

621.385.833 228  
New Formulae for the Third-Order Aberrations of Magnetic Lenses—R. Sturrock. (*Compt. Rend. Acad. Sci.* (Paris), vol. 233, pp. 146–147; July 9, 1951.)

621.385.833:621.317.42 229  
Inductance Method for studying the Field Pattern on the Axis of a High-Power Magnetic Electron Lens—Fert and Gautier. (See 195.)

621.387.4† 230  
A Localizing Geiger Counter—S. G. F. Frank. (*Phil. Mag.*, vol. 42, pp. 612–615; June, 1951.) A method is described for locating ionizing particles, based on the fact that the discharge in a Geiger counter spreads along the wire at a constant speed.

621.387.462† 231  
Behavior of Space Charge in Diamond Crystal Counters under Illumination; Part 1—A. G. Chynoweth. (*Phys. Rev.*, vol. 83, pp. 254–263; July 15, 1951.)

621.387.462† 232  
Behavior of Space Charge Free Diamond Crystal Counters under Beta-Ray Bombardment: Part 2—A. G. Chynoweth. (*Phys. Rev.*, vol. 83, pp. 264–268; July 15, 1951.)

621.39.001.11:6 233  
Cybernetics—J. Loeb. (*HF* (Brussels), no. 10, pp. 257–269, 286; 1951.) The development of the subject as a theory of telecommunication signals is outlined, and its application to calculating machines and to servo-mechanisms is described, together with wider applications in physiology, psychology, and the political economy.

681.142 234  
Step Multiplier in Guided Missile Computer—E. A. Goldberg. (*Electronics*, vol. 24, pp. 120–124; August, 1951.) A 4,000-tube analogue computer for simulating the characteristics of a missile-target system includes a high-precision multiplier comprising reversible binary counter and relay-operated conductance networks for maintaining orthogonality between the reference-axis systems of earth and missile as the computation proceeds.

681.142 235  
Some Aspects of Electrical Computing—J. Bell. (*Electronic Eng.*, vol. 23, pp. 213–216 and 264–269; June and July, 1951.) An account of the application of various devices in the design of equipment for conversion from polar to cartesian co-ordinates, or vice versa, differentiation, integration, multiplication, division, and computation of variable functions relating to ballistics. These devices include (a) the ipot (inductive potentiometer), a toroidal coil very uniformly wound on a large ring core and provided with sliding contacts, and (b) the magstrip resolver, a special type of servo-mechanism.

## PROPAGATION OF WAVES

538.566 236  
‘Internal’ Reflection in a Stratified Medium with Application to the Troposphere—G. Eckart and T. Kahan. (*Arch. Elektrotech.*, vol. 40, no. 2, pp. 133–140; 1951. German version of 718 of 1951.)

536.566 237  
Properties of Inhomogeneous Plane Electromagnetic Waves—Bonfiglioli. (See 113.)

538.566:535.42 238  
Diffraction of Electromagnetic Waves near the Earth's Surface in an Optically Inhomogeneous Medium—R. Schachenmeier. (*Arch. elekt. Übertragung*, vol. 5, pp. 267–272; June, 1951.) Making use of the laws of geometrical optics and non-Euclidean geometry, the problem is transformed to render it amenable to calculation by methods already developed. For practical calculations, the actual curvature of the earth's surface is reduced by that of the ray path when the ordinary laws of diffraction can be used.

621.396.11+621.392.2.09 239  
Characteristic Impedance, Power, Voltage and Current in Transmission along Lines, in Waveguides and in Free Space—Zinke. (See 31.)

621.396.11 240  
A V.H.F. Field-Strength Survey on 90 Mc/s—H. L. Kirke, R. A. Rowden, and G. I. Ross. (*Proc. IEE*, vol. 98, pp. 343–359; discussion, pp. 378–382; September, 1951.) The effects of the height of the site and of the transmitting antenna, and the profile of the transmission path, are discussed in relation to field-strength measurements for a transmitter at Wrotham, Kent. In built-up areas the variations are less for horizontal than for vertical polarization. In hilly country the minimum field strength occurs on the near-side slope of a valley, and is lower for horizontal than for vertical polarization. Measurements along radials show that, in general, signals of these two polarizations are propagated equally well. By extrapolating from these data, a field-strength contour map of S.E. England has been prepared for a transmitter power of 25 kw and high-gain antenna on a 500-foot mast.

621.396.11 241  
The Propagation of Metre Radio Waves beyond the Normal Horizon: Part 1—Some Theoretical Considerations, with Particular Reference to Propagation over Land—J. A. Saxton. (*Proc. IEE*, vol. 98, pp. 360–369; discussion, pp. 378–382; September, 1951.) The relative importance of abnormally high refraction near the surface of the earth, and of reflection from high-level inversion layers, is investigated and illustrated by examples. Of the two mechanisms, the latter is the more likely to give abnormally high field strength at ranges of a few hundred kilometers, especially for low terminal heights. Consideration is also given to the effects of scattering by turbulent eddies in the atmosphere. This is of less importance than other mechanisms of propagation up to distances of 250 km.

621.396.11 242  
The Propagation of Metre Radio Waves beyond the Normal Horizon: Part 2—Experimental Investigations at Frequencies of 90 and 45 Mc/s—J. A. Saxton, G. W. Luscombe, and G. H. Bazzard. (*Proc. IEE*, vol. 98, pp. 370–378; discussion, pp. 378–382; September, 1951.) The statistical distribution of quasi-peak field strength as a function of time was determined for propagation over two paths of respective lengths 110 and 270 km at 90 mc, and over one of length 160 km at 45 mc, for a period of two years. The observed field strengths often considerably exceeded the values corresponding to standard atmospheric refraction. Some degree of correlation was found with meteorological data obtained from routine radiosonde ascents. Use of the results in planning vhf broadcasting services is outlined. Part 1: 241 above.

621.396.11:551.510.535 243  
Vertical Propagation of Electromagnetic Waves in the Ionosphere—M. N. Saha, B. K. Banerjee, and U. C. Guha. (*Proc. Nat. Inst. Sci.* (India), vol. 17, pp. 205–226; May–June, 1951.) A discussion of the equations for vertical propagation in the ionosphere is given in standardized notation. The electric vector components  $E_x$  and  $E_y$  are coupled by polarization terms  $p_1$  and  $p_2$  which are functions of geomagnetic latitude and height. The propagation vectors associated, respectively, with the ordinary and extraordinary waves are given by  $(E_x + ipE_y)/\sqrt{+p^2}$  for two different values of  $p$ , and are governed by two refractive indices  $q_0$  and  $q_e$  and a coupling term  $\phi$ . The five quantities needed to define wave propagation completely are  $p_1$ ,  $p_2$ ,  $\phi$ ,  $q_0$ , and  $q_e$ . The first three of these are discussed here; the last two have been dealt with by Booker (see e.g., 355 of 1935) and others. For  $F$ -layer propagation,  $\phi$  can be neglected everywhere except very near the geomagnetic poles.  $E$ -layer propagation is more difficult to calculate.

621.396.11:551.510.535 244  
Lateral Deflection of the Ray on Reflection at an Inhomogeneous Ionosphere Layer—K. Rawer. (*Z. angew. Phys.*, vol. 3, pp. 226–227; June, 1951.) General and numerical calculation of azimuth variation caused by lateral ray displacement, based on particular ionosphere models. The deflection is in the direction of stronger ionization, and angular displacement of nearly  $10^\circ$  occurs, corresponding to an increase of 10 per cent in the muf. Good agreement with observations is noted.

621.396.11.012.3 245  
Field Power Conversion—R. E. Perry. (*Electronics*, vol. 24, p. 134; August, 1951.) A chart is shown for converting propagation data from field-strength to power-density values.

621.396.11.029.51:551.510.535 246  
Effects of Ionosphere Disturbances on Low Frequency Propagation—J. M. Watts and J. N. Brown. (*Jour. Geophys. Res.*, vol. 56, pp. 403–408; September, 1951.) Some photographic records of ionospheric reflections obtained with a transmitter giving a peak pulse power of 900 kw on frequencies of 50, 100, and 160 kc, are reproduced and discussed. The disturbed appearance of the  $E$ -region night-time echoes is found to be a sensitive indication of storminess. In the daytime the effect of storms is to cause an increase in absorption, with a corresponding weakening or fade-out of  $E$  echoes. A graph is given showing correlation between magnetic activity and night-time disturbance of the  $E$  layer.

621.396.11.029.51:551.510.535 247  
A Method for Obtaining the Wave Solutions of Ionospherically Reflected Long Waves, including all Variables and their Height Variation—Gibbons and Nertney. (See 137.)

## RECEPTION

519.272.15:621.39.001.11 248  
**The Electronic Correlator**—H. Doizelet. (*Rad. Tech. Dig.* (France), vol. 5, no. 4, pp. 187–200; 1951.) The problem of improving amplifier sensitivity in spite of irreducible background noise is considered in relation to statistical information theory. The autocorrelation function for noise voltage vanishes for large values of the time interval, while the autocorrelation function for a periodic voltage is itself periodic. This affords a method for separating the two voltages. The operation of the correlator constructed at the Massachusetts Institute of Technology is described. See also 730 of 1951 (Lee, Cheatham, and Wiesner).

621.396.61/:62:621.396.67 249  
**Transmission and Reception of Circularly Polarized Microwaves with a Common Aerial**—Ruppel. (See 281.)

621.396.62+621.395.625[:061.4 250  
**The Radio Exhibition at the Vienna Spring Fair**—(*Radio Tech.* (Vienna), vol. 27, pp. 195–198; April, 1951.) Review of portable receivers and magnetophone recording equipment exhibited.

621.396.621 251  
**Short-Wave Receivers**—H. Flicker and J. Hacks. (*Telefunken Ztg.*, vol. 24, pp. 27–38; March, 1951.) An account of present-day technique used in the construction of commercial SW receivers. The properties that can reasonably be expected in a receiver are considered, and also how far such requirements are mutually exclusive or concordant. Technical data for twelve modern receivers of German, French, British, and American manufactures are tabulated. The propagation of short waves is discussed in relation to receiver characteristics.

621.396.621.001.4 252  
**Systematic Analysis of the Properties of Radio Receivers**—É. Fromy. (*Onde élect.*, vol. 31, pp. 210–222 and 282–291; May and June, 1951.) A technique of receiver performance evaluation is described which overcomes the inadequacy of the usual specifications of sensitivity. For the receiver hf amplifier, a cw source is used to derive a family of curves, relating antenna input voltage to detector output, for gradually increasing values of amplification. This is linked with a corresponding family of curves for set noise as a function of input voltage. The af amplifier, with gain control at maximum, and the controls in earlier stages adjusted so that set noise at the output terminals is inappreciable, is treated similarly, its characteristics being obtained by varying the voltage applied to the receiver input terminals. The interpretation of the performance characteristics so obtained is discussed, and examples are given.

621.396.621.54:621.3.012.3 253  
**New Diagrams for 'Ganging' Calculation**—Kerbel. (See 53.)

621.396.622+621.396.619.2 254  
**Modulators, Frequency Changers and Detectors using Rectifiers with Frequency-Dependent Characteristics**—Tucker. (See 282.)

621.396.622 255  
**The Relative Advantages of Coherent and Incoherent Detectors: A Study of their Output Noise Spectra under Various Conditions**—R. A. Smith. (*Proc. IEE*, vol. 98, pp. 401–406; September, 1951.) Summary of IEE Monograph No. 6. Comparison is made of output spectra obtained with incoherent square-law and linear detectors on the one hand, and coherent homodyne and commutator detectors on the other hand, for an input comprising sinusoidal signal plus noise. Input noise from several common types of filter is considered. Curves give the signal-to-noise ratio at the output when no further bandwidth limitation is ap-

plied, and when the detector is followed by a narrow-band filter. Considerable advantage can be obtained with a coherent detector when the input signal-to-noise ratio is somewhat less than unity.

621.396.8.029.45 256  
**Overseas Reception on Medium Waves**—K. M. Schwarz. (*Radio Tech.* (Vienna), vol. 27, p. 224; May, 1951.) Near-East stations often heard in Europe are listed. Reception of medium-wave programs from South America is subject to long-period fading (up to several minutes), but is considerably more regular than for SW stations.

621.396.823 257  
**Radio Influence Tests in Field and Laboratory—500-kV Test Project**—G. D. Lippert, W. E. Pakala, S. C. Bartlett, and C. D. Fahrnkopf. (*Elec. Eng.*, vol. 70, pp. 481–486; June, 1951.) A 1951 AIEE Winter General Meeting paper. Report of an investigation of the effect on the unwanted rf radiation from 500-kv lines of weathering, precipitation and variation of voltage, frequency, and conductor diameter.

## STATIONS AND COMMUNICATION SYSTEMS

621.39.001.11 258  
**A History of the Theory of Information**—E. C. Cherry. (*Proc. IEE*, vol. 98, pp. 383–393; September, 1951.) Fundamental points in human communication systems which have been summarized by precise mathematical theory are mentioned. The need for economy, which appeared as telegraphy and telephony developed, led to systems of signal compression and early theories of communication, later extended to express "information" quantitatively. Definite accomplishments in the mechanization of processes analogous to thought, as embodied in calculating machines and servomechanisms, are outlined. Evidence from the whole field of scientific observation supports the view that "information plus entropy is an important invariant of a physical system."

621.395.44 259  
**German Carrier-Frequency System V60**—W. Zerbel. (*Fernmeldetech. Z.*, vol. 4, pp. 193–201 and 268–274; May and June, 1951.) The carrier-frequency arrangements which will be used by the German Post Office on its new long-distance cable network are described, with particular reference to the electrical aspects (pre-grouping or pre-modulation system for sixty channels) and the practical construction.

621.395.665.1 260  
**Instantaneous Companders**—C. O. Malinkrodt. (*Bell Sys. Tech. Jour.*, vol. 30, pp. 706–720; July, 1951.) Discussion of the theory of the "instantaneous" type of compander, and evaluation of the noise advantage when instantaneous companding is applied to telephone channels.

621.396.5:621.396.931 261  
**Experimental Radio-Telephone Service for Train Passengers**—N. Monk. (*Proc. I.R.E.*, vol. 39, pp. 873–881; August, 1951.) A series of stationary transmitters and receivers working in the 35- to 45-mc band, and situated along the 440-mile railway from New York to Buffalo, provide links between trains and the normal telephone system. Train attendants were formerly required, but experiments with coin-boxes have been successful. In this case the frequency band 152 to 162 mc is used.

621.396.61/:621:621.396.931 262  
**New Equipment for V.H.F. Radio-Telephone Systems**—(*GEC Telecommun.*, vol. 3, no. 1, pp. 5–14; 1948.) AM and FM transmitter-receivers for mobile and central stations are described. All units are crystal controlled and will operate at any frequency in the bands allocated between 30 and 184 mc. Miniature tubes and components are used, enabling the

complete equipment for one station to be contained in a box 8 inches×18 inches×8 inches. Public-address facilities are incorporated.

621.396.61/:621:621.396.931 263  
**High-Frequency Radio Transportable Transmitter and Receiver**—(*GEC Telecommun.*, vol. 4, no. 1, pp. 12–22; 1949.) A description of apparatus suitable for cw or mcw telegraphy and AM telephony; the weight of which is 60 lbs. Power supply may be at 12 or 24 v dc, or from 50-cps mains. The transmitter, covering the frequency range 2 to 9.1 mc, comprises a crystal oscillator and modulated amplifier stages, and radiates 25 w on cw telegraphy. The modulation amplifier may be used alternatively for public-address purposes. The superheterodyne receiver covers the band 2 to 20 mc.

621.396.619.14 264  
**Product Phase Modulation and Demodulation**—D. B. Harris. (*Proc. I.R.E.*, vol. 39, p. 907; August, 1951.) Correction to paper noted in 3159 of 1950.

621.396.65 265  
**New Directional [radio] Links**—J. Kornfeld. (*Radio Tech.* (Vienna), vol. 27, pp. 164–167; April, 1951.) Review of American and European wide-band relay networks for long-distance communications and television services.

621.396.65 266  
**Application of Microwave Channels**—R. C. Check. (*Elec. Eng.*, vol. 70, pp. 500–503; June, 1951.) A 1951 AIEE Winter General Meeting paper. Relevant factors in the design of microwave communication systems are considered, including the selection of frequency band, the influence of topography on the choice of terminal sites, the calculation of the free-space loss between antennas, which determines the antenna size, and the losses in cables or waveguides between the equipment and antennas.

621.396.65:621.396.619.13 267  
**Asymmetry of the Frequency Swing, particularly in the case of Wide-Band F.M. Directional Links**—P. Barkow. (*Fernmeldetech. Z.*, vol. 4, pp. 168–173; April, 1951.) The cause of the asymmetry and of the consequent distortion is analyzed, and methods of correcting and of compensating the errors of symmetry are described.

621.396.65.029.62:621.396.5 268  
**Conditions for the Development in France of Two-Way Radiotelephony on Very Short Waves**—E. P. Courtillot. (*Onde élect.*, vol. 31, pp. 223–232; May, 1951.) The use of the frequency band 25 to 174 mc for two-way communication between fixed and mobile stations is discussed generally in the light of current practice in the United States and in England. It is essential to arrange development according to a fixed plan, taking full account of economic factors.

621.396.97:621.396.66 269  
**The Automatic Monitoring of Broadcast Programmes**—H. B. Rantzen, F. A. Peachey, and C. Gunn-Russell. (*Proc. IEE*, vol. 98, pp. 329–340; discussion, pp. 340–342; September, 1951.) See 1491 of 1951.

## SUBSIDIARY APPARATUS

621.314.1.082.72 270  
**Electrostatic Direct-Current Transformer of 300 Kilovolts**—J. M. Malpica. (*Rev. Sci. Instr.*, vol. 22, pp. 364–369; June, 1951.) A continuous transfer of electric charges is effected by rotating a dielectric between two pairs of metallic brushes, the primary pair being connected to an hv source. Several disks on one shaft are used to form a stepup transformer. The elementary theory and experimental results are given.

621.314.632.1 271  
**Resistance Stratification in Copper-Oxide Rectifiers: Part 1—Investigations on Massive**

**Plates with Nonblocking Contacts**—F. Rose. (*Ann. Phys. (Lpz.)*, vol. 9, pp. 97-123; June 30, 1951.) Measurements of the apparent resistance of massive oxidized copper disks with graphite or silver contacts were carried out at frequencies up to 100 kc and at various temperatures in the range 195° to 303°K. The results obtained are presented in a table, and diagrams, and are discussed with particular reference to Lehovc's method of estimating the conductivity distribution through the oxide layer.

**621.314.632.1** 272  
**Resistance Stratification in Copper-Oxide Rectifiers: Part 2—Investigations on Rectifier Disks**—F. Rose. (*Ann. Phys. (Lpz.)*, vol. 9, pp. 124-140; June 30, 1951.) Measurements were made for the same frequency and temperature ranges as for massive disks (271 above) on rectifier disks of two sorts of copper subjected to various annealing conditions, again using graphite or silver electrodes. The results are shown in diagrams, and Lehovc's method of analysis is applied.

**621.316.722.078.3** 273  
**Stabilization of Direct Voltages**—H. Günther. (*Funk u. Ton*, vol. 5, pp. 124-132; March, 1951.) Discussion of the maximum stability attainable using an amplifier tube as a series resistance. Suitable conductance characteristics for the controlling pentode are shown. Its anode load resistance should be as large as possible. An additional potentiometer-type control circuit at the input reduces input voltage fluctuations and reduces the effective internal resistance of the control circuit.

**621.319.3** 274  
**New Electrostatic Generators**—N. J. Félici. (*Onde élect.*, vol. 31, pp. 205-209; May, 1951.) The general principles underlying the functioning of rotary es generators are outlined. The necessity for a fluid dielectric with high breakdown voltage has led to the use of compressed gas, usually air. Pressures of thirty atmospheres enable the power output of a machine to be made two hundred times greater than is possible with normal atmospheric pressure. Figures are quoted for several existing machines, giving outputs of up to 100  $\mu$  A at 500 kv. Machines are being developed for outputs as high as 30 mA at 500 kv or more. An over-all efficiency of 75 per cent is readily obtained. See also 999 of 1951. (Hémandinquer)

#### TELEVISION AND PHOTOTELEGRAPHY

**621.397.5** 275  
**The Evaluation of Picture Quality with Special Reference to Television Systems: Part 1**—L. C. Jesty and N. R. Phelps. (*Marconi Rev.*, vol. 15, pp. 113-136; 3rd Quarter, 1951.) "A new method of assessing the performance of a picture reproducing system is described. The effect of the simultaneous variation of the four parameters, brightness, contrast, resolution, and viewing distance, has been explored. Measurements have been made under conditions of best picture reproduction, with the system maintained at this level of adaptation. Various photographic and television systems have been examined. This work has involved a similar investigation of the behavior of the 'average observer'."

**621.397.5:535.62** 276  
**A Color Television System for Industry**—H. R. Smith, A. L. Olson, and R. F. Cotellessa. (*Elec. Eng.*, vol. 70, p. 517; June, 1951.) Summary of 1951 AIEE Winter General Meeting paper. Description of a wired system using an Orthicon camera tube and suitable for industrial, commercial, medical, and military applications. A field-sequential system with rotating color disks is used.

**621.397.5:535.62(083.74)** 277  
**Plans for Compatible Color Television**—D. G. F. (*Electronics*, vol. 24, pp. 90-93; August, 1951.) System standards recommended

by the U. S. National Television System Committee are outlined. A composite signal is suggested, including a monochrome component and a color component on a subcarrier. Field tests are to be made in order to formulate definite numerical proposals for a full set of compatible color standards.

**621.397.5:535.623** 278  
**Dot-Interlaced Scanning and its Recent Development in American Colour Television**—E. Schwartz. (*Fernmeldelech. Z.*, vol. 4, pp. 243-250; June, 1951.) The four-raster system of point scanning is explained, and new pulse technique for this method of scanning is described. Its application to color television is examined in detail, and suitable tubes developed for the purpose in the United States are briefly described.

**621.397.5:621.317.74** 279  
**Transmission Measuring System**—Engstrom. (See 208.)

#### TRANSMISSION

**621.316.726.078.3** 280  
**U.H.F. Discriminator and its Application to Frequency Stabilization [of klystron]**—Pircher. (See 59.)

**621.396.61/.62:621.396.67** 281  
**Transmission and Reception of Circularly Polarized Microwaves with a Common Aerial**—W. Ruppel. (*Fernmeldelech. Z.*, vol. 4, pp. 251-253; June, 1951.) By using both directions of rotation of circularly polarized waves, an antenna system can be used for both the transmission and reception of waves of the same frequency. The bridge arrangement for decoupling the energy paths is explained, and a practical example is described which embodies two tank circuits. Arrangements of compact linear elements avoid the use of a gas-filled blocking tube. The principle is, in practice, only applicable to microwaves.

**621.396.619.2+621.396.622** 282  
**Modulators, Frequency Changers and Detectors using Rectifiers with Frequency-Dependent Characteristics**—D. G. Tucker. (*Proc. IEE*, vol. 98, pp. 394-398; September, 1951.) An approximate method of allowing for frequency dependence of the resistance characteristic of the rectifier can be applied easily to the analysis of circuits where the terminating impedances are finite only at a finite number of modulation-product frequencies, and zero at all other frequencies. Results for a particular set of operating conditions are illustrated by numerical examples based on copper-oxide modulators working at frequencies up to 6 mc. The conversion insertion-loss can be stabilized against temperature variation by a suitable choice of terminating resistance. The working and results are the same for shunt, series, and ring modulators for conditions of low input frequency with high output frequency, and vice versa.

**621.396.619.23** 283  
**Oscillator Circuits as Frequency Modulators**—W. Mansfeld. (*Funk u. Ton*, vol. 5, pp. 309-316, 351-360, and 411-421; June to August, 1951.) Three different arrangements are investigated theoretically and experimentally, and it is shown that proportional frequency variations can be obtained by modulation of the feedback phase angle. Using a single-tube oscillator circuit, a frequency swing of over 6 per cent was obtained, with linearity over a wide range, but a disadvantage of this modulator circuit is the dependence of the excited frequency on the operating voltages and tube characteristics. A push-pull circuit with push-pull modulation gave much better results, the linearity, frequency swing obtainable, small amplitude variation with modulation voltage, and frequency constancy with variations of operating voltage making such an arrangement useful as a frequency modulator. Another push-pull circuit, incorporating a phase-control arrangement, also gave good results.

#### TUBES AND THERMIONICS

**621.383.277:621.317.42** 284  
**Investigation of the Conditions for Use of Kubetski's Mosaic Multiplier as an Indicator of the Magnetic Field**—N. V. Krasnogorskiya. (*Bull. Acad. Sci. U.R.S.S., sér. géogr. géophys.*, vol. 15, pp. 43-50; January-February, 1951. In Russian.) A multiplier with a CuS-Cs photocathode and six stages of electron multiplication is described. Each stage consists of a secondary-emission CuS-Cs electrode and a nonemitting Ag electrode. The alternation of dark emitting and bright nonemitting layers resembles a mosaic. The electrons leaving the photocathode are directed by means of an electric and a magnetic field. An additional magnetic field shifts the beam from sensitive to nonsensitive electrodes, thus altering the value of the anode current. Experiments with these multipliers are described. The necessary conditions of stability of the power supplies are derived for a given accuracy of measurement of the intensity of the magnetic field, and limits of possible measurements are established.

**621.385.029.63/.64:537.533** 285  
**Waves in Electron Streams and Circuits**—Pierce. (See 106.)

**621.385.3:546.289** 286  
**Electronic Forming in n-Germanium Transistors using Phosphorus-Alloy Contacts**—J. P. Stelmak. (*Phys. Rev.*, vol. 83, p. 165; July 1, 1951.) Results of measurements emphasize the important role played by the P content of the collector contact point in improving transistor gain when forming is done by pulsed currents.

**621.385.5:621.318.572** 287  
**High-Speed Sampling Techniques**—Shepard. (See 64.)

**621.385.82.029.3:621.395.61** 288  
**Increasing the Efficiency of the High-Power Thermionic Cell by Superposition of a Strong Field obtained from a High Voltage of High Frequency**—S. Klein. (*Compt. Rend. Acad. Sci. (Paris)*, vol. 233, pp. 143-145; July 9, 1951.) Modifications to the gas-filled thermionic cell described in 593 of 1947 are proposed. An hf voltage applied to a Pt point produces a discharge which heats the ion emitter. The device can be used both as an acoustic and ultrasonic transducer, and as a source of ultraviolet radiation.

**621.396.615.141.2:621.385.029.63/.64** 289  
**The Magnetron as a Traveling-Wave Valve**—O. Döhler. (*Funk u. Ton*, vol. 5, pp. 146-155 and 257-262; March and May, 1951.) Treatment of the theory, and description of the construction and operation of different types of magnetron. Complementary to paper noted in 1017 of 1951. See also 2064 of 1950 (Warnecke et al.).

**621.38** 290  
**Electronics [Book Review]**—P. Parker. Publishers: Arnold, London, England, 1950 pp., 50s. (*Jour. Sci. Instr.*, vol. 28, pp. 223; July, 1951.) "In this admirably balanced work there is no subject which is over-elaborated, or in which the reader is not brought up to a level just short of research standard."

#### MISCELLANEOUS

**621.39.001.5** 291  
**Telecommunications Research: Fundamental Investigations Undertaken by the D.S.I.R.**—(*Wireless World*, vol. 57, pp. 431-432; October, 1951.)

**621.396:061.4** 292  
**Radio Exhibition Review**—(*Wireless World*, vol. 57, pp. 384-395; October, 1951.) Trends in the design of radio, television, and associated apparatus shown at the 18th National Radio Exhibition, held in London during September, 1951, are illustrated and discussed.

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**OP 827 TRANSFORMERS**  
*manufactured with*  
**CANS & TERMINALS**  
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**COMPONENTS**  
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**SPECIFICATIONS**



Standard Transformer Corporation, one of the nation's leading transformer manufacturers, selected HELDOR CANS and TERMINALS as the ideal components for the design and production of their Stancor OP 827 Transformer . . . built from start-to-finish to pass MIL-T-27 specifications.

If you have any problems with Hermetic Seal Bushings, avail yourself of Heldor's free engineering counsel.

Whether your products must meet government specifications or not, it will pay you to standardize on HELDOR CANS, COMPRESSION-TYPE HERMETIC SEAL BUSHING ASSEMBLIES or COMPLETELY ASSEMBLED UNITS.

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225 Belleville Ave., Bloomfield, N. J.	
Please send me prices and specifications on MIL-T-27 cans and bushings.	
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Company .....	
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**HELDOR MANUFACTURING COMPANY**  
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VISIT BOOTH S-17 AT THE RADIO ENGINEERING SHOW, GRAND CENTRAL PALACE, MARCH 3-6

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TUNGSTEN and MOLYBDENUM  
GRID WIRE . . . and other Wire of

*Smaller than Commercial Sizes*

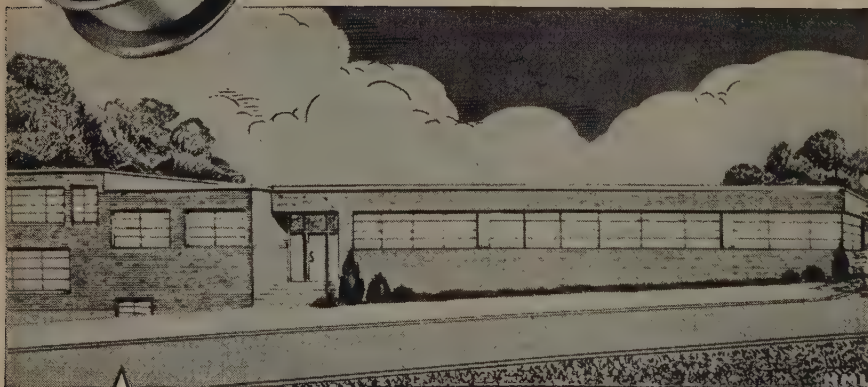
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## Industrial Engineering Notes<sup>1</sup>

### RESEARCH

The possibilities of using a ceramic material, barium titanate, as an amplifier in an electronic circuit is indicated in a Signal Corps developmental report made available through the Office of Technical Services, Department of Commerce. The report points out that a study of barium titanate at high frequencies reveals that it has a high dielectric constant which varies with applied alternating voltage. Hence, it could be used to produce amplification in electronic circuits in place of vacuum tubes. The report, PB 104 394, "Development and Application of Barium Titanate Ceramics as Non-Linear Circuit Elements," sells for \$2.50 in microfilm and \$5.00 in photostat form. . . . The recent completion of a new model antenna range to facilitate the measurement of antenna radiation patterns in the vertical plane has been announced by the National Bureau of Standards. The range is believed by NBS to be the largest ever designed for this purpose. It is composed of an inverted "V"-type structure which supports a test or target transmitter more than fifty feet above the ground plane, in the center of which is placed the model antenna to be tested. The range was designed and built under the supervision of H. V. Cottony at the NBS Radio Propagation Station in Sterling, Va. Complete information on the model antenna range can be found in the NBS Technical News Bulletin for December, 1951. . . . The November, 1951 issue of the "Bibliography of Technical Reports," released by the Office of Technical Services, Department of Commerce, includes reports on the investigation of magnetic recording systems and synthetic mica research. The "Bibliography of Technical Reports" is available for \$0.50 per copy through the Office of Technical Services in Washington, or Department of Commerce field offices.

### MORE THAN FOUR MILLION TV SETS AND TEN MILLION RADIOS PRODUCED

More than 4 million television receivers and 10.9 million radios were manufactured in the first ten months of 1951, according to industry estimates comprised for RTMA. However, this represented a decrease of more than two million of both radios and TV receivers under the production in the corresponding period of 1950.

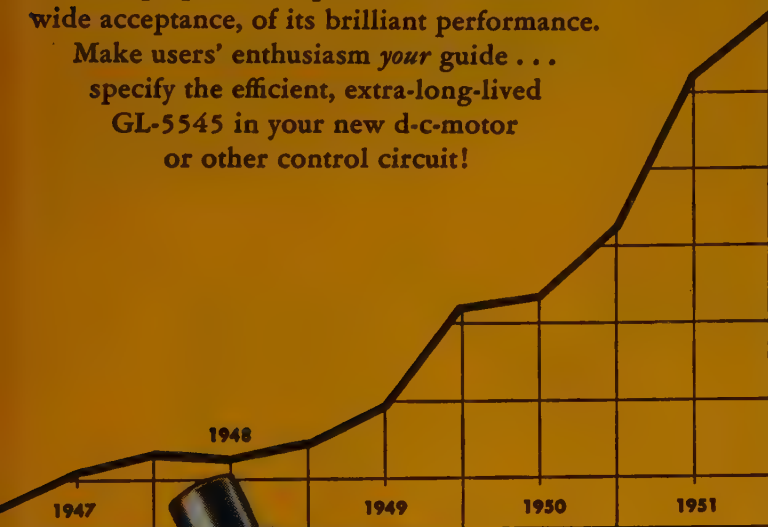
### FCC ACTIONS

Chairman Wayne Coy of the Federal Communications Commission has predicted that the FCC could "resume issuing construction permits (for TV stations) even as early as the first of April." The FCC Chairman spoke to a TV conference sponsored by the Radio Commission of the Southern Baptist Convention in Washington. "There is a terrific pent-up demand

(Continued on page 102A)

# CHOOSE THE TUBE ALL INDUSTRY IS BUYING!

**GL-5545 Thyatron** sales have climbed spectacularly since introduction. Their sharp up-curve is proof of the tube's wide acceptance, of its brilliant performance. Make users' enthusiasm *your* guide . . . specify the efficient, extra-long-lived GL-5545 in your new d-c-motor or other control circuit!



**COMPARE!** Why is the GL-5545 showing its heels to similar types? Compare this G-E control tube point-by-point with other-make thyatrons rated the same capacity:

CHARACTERISTIC	GL-5545	TUBE "A"	TUBE "B"	TUBE "C"
Avg current	6.4 amp	Same	Same	Same
Peak current	80 amp	LOWER	LOWER	LOWER
Fault current	1,120 amp	LOWER	LOWER	LOWER
Max voltage, peak forward	1,500 v	LOWER	LOWER	LOWER
Max voltage, peak inverse	1,500 v	LOWER	LOWER	LOWER
Ambient temp range	-55 to +70 C	Same	LOWER	Same
Commutation factor*	130	LOWER	LOWER	LOWER
Snubber circuit needed?	No	YES	YES	YES
Shielded grid construction?	Yes	NO	NO	NO

\*Commutation factor is the product of the rate of decay of current in amperes per microsecond just before commutation, and the rate of rise of inverse voltage in volts per microsecond just after commutation.

For complete performance facts . . . for application counsel . . . wire or write **Electronics Division, General Electric Company, Schenectady 5, New York.**



**GL-5545**  
**6.4-amp THYRATRON**



**GENERAL  ELECTRIC**

# PRECISION RESISTORS of Timely Importance

## Industrial Engineering Notes

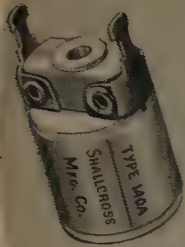
(Continued from page 100A)

for television," Mr. Coy said. "The demand is from vast areas of our country that don't have it and it is from hundreds of entrepreneurs who are itching to become station operators. Soon after the freeze is lifted we expect to have some 1,000 applications for construction permits. In other words, almost a billion dollars has already been earmarked by various corporations and individuals to construct our new television stations." Mr. Coy speculated that in five years "we will have 1,200 to 1,500 TV stations on the air and in ten years we may have 2,500." . . . The FCC recently issued a notice of proposed rule-making looking toward the formalization of its present policy on collecting patent information. The proposed rule will require "each person who owns one or more unexpired United States patents, or has the right to license others under one or more such patents owned by others, which are being used for rendering telephone, telegraph, cable or radiotelephone carrier service to the public, or being used for safety and special services, or for rendering radio broadcast services to the public; and said person renders a part of, or all of, the service or services for which said patents are being used, or controls, or is controlled by, the person who renders a part of, of all of, said service or services, or is under direct or indirect common control with the person or persons rendering a part of, or all of, the service or services for which said patents are being used, to prepare and file, in duplicate, with the Commission on or before the 31st day of March of each year, verified under oath (or affirmed according to law) and covering the period of twelve months ending on the 31st day of December next prior to said date, certain information as to the use and licensing of said patents."

### RTMA ACTIVITIES

E. W. Merriam, who has served as RTMA Service Manager on a temporary basis since early in October, 1951, has been appointed Service Manager of the Radio and Television Division of Sylvania Electric Products Inc. Mr. Merriam plans to continue to devote a portion of his time to RTMA activities until a successor is appointed by the Association. . . . The RTMA Engineering Department has prepared a fourteen-point chart on the subject of electronic equipment reliability. The chart, which is printed in color, is suitable for use on the walls or at the desks of equipment designers. Copies of the chart were mailed to all member companies. RTMA prepared the chart at the suggestion of and with the assistance of the Directors of the Armed Services Electro Standards Agency. It represents a step in an RTMA program to increase the reliability of military, industrial, commercial, and home entertainment equipment through the proper selection and application of components. The chart calls attention to the fact that reliability depends upon each component being used in the circuit under conditions established by its own capabilities.

(Continued on page 104A)

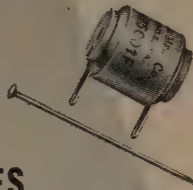


### VERTICAL STYLE JAN-R-93

Flush terminals extending vertically from the same end of this Shallcross BX Type precision wire-wound resistor provide longer leakage path from mounting surface and simplify mounting in many applications . . . Designed to meet JAN requirements for styles RB40B, RB41B and RB42B.

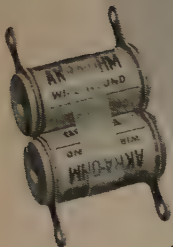
### HERMETICALLY-SEALED LUG-TYPE MIDGETS

Designed for JAN-R-93, characteristic A, style RB11, these resistors are only  $\frac{1}{32}$ " long x  $\frac{1}{2}$ " diameter. Values up to 0.1, 0.3 or 0.4 megohms depending on alloy of windings. Hermetic sealing by a patented Shallcross process provides positive protection against humidity, fungus and salt water immersion.



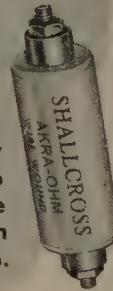
### HIGH-STABILITY TYPES

Most of the more than 50 standard Shallcross resistors can be supplied to a tolerance as close as 0.01% and with guaranteed stability of 0.003%. Shallcross also regularly supplies matched pairs and sets. Special resistors of this type require extra processing precluding possibility of quick delivery. In designing new equipment with quantity production anticipated, standard (0.05% to 1%) units are recommended for best delivery and price.



### PRECISION POWER RESISTORS

Practically any standard Shallcross Akra-Ohm resistor (including miniature types) can be supplied with glass fibre insulated wire and silicone impregnation to increase power rating from 2 to 4 times while retaining accuracy and stability. Ratings range from 1 watt for miniatures to 20 watts for the largest bobbin size. Glass insulated wire limits maximum resistance available on a given bobbin to lower than usual values as tabulated in bulletin R-3b.



**A complete assortment of precision wire-wound resistor sizes, styles, ranges and mountings for military or industrial use. Write on company stationery for Shallcross Akra-Ohm Engineering Bulletin R-3b to Shallcross Manufacturing Company, Collingdale, Pa.**

# SHALLCROSS

PRECISION RESISTOR SPECIALISTS FOR OVER 20 YEARS

THE SOLA FAMILY OF

# 5 Voltage Regulator Types

MEETS MOST  
MILITARY and INDUSTRIAL  
REQUIREMENTS

## SOLA standard type CV:



Regulation  $\pm 1\%$

These transformers are made under one or more of the following patents:

2,143,745  
2,212,198  
2,346,621  
2,552,111  
2,489,245  
and patents pending.



SOLA DISCIPLINES VOLTAGE

## SOLA adjustable, harmonic filtered type CVL:

Regulation  $\pm 1\%$   
Harmonic Distortion less than 3%  
Output adjustable from 0-130 volts



## SOLA television receiver type CVA:

Regulation  $\pm 3\%$   
Plug-in accessory unit



## SOLA plate and filament type CVE:

Regulation  $\pm 3\%$



## SOLA harmonic filtered type CVH:



Regulation  $\pm 1\%$   
Harmonic Distortion less than 3%

## CHARACTERISTICS OF SOLA CONSTANT VOLTAGE TRANSFORMERS

- Static-magnetic regulation
- Ultra-fast response (1.5 cycles)
- No moving or renewable parts
- No manual adjustments
- Complete automatic, continuous regulation
- Self-protecting against short circuits
- Automatic current limiting action
- Choice of transformation ratios

We invite you to write regarding your voltage regulating problems, or for inclusion of your name on our technical mailing list.

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There's a **NEW SILHOUETTE**  
on the Broadcast Horizon . . .

## THE NEW ULTRA-CARDIOID DYNAMIC

SMALL  
**Broadcast**  
MICROPHONE



MODEL 556s  
List Price \$100

The new "Small Broadcast" is approximately only half as large as the Standard Broadcast

► Reduces pickup of random sound energy by 67%

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### BIG IMPROVEMENTS HAVE BEEN MADE ON THIS ALL NEW MICROPHONE

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The internal unit is based on the Shure-patented "Uniphase" principle. The moving-coil system has a high over-all efficiency and smooth extended frequency response. Large air-gap clearances and a rugged coil construction provide immunity of the moving coil system to abnormal atmospheric conditions and severe mechanical shocks. The 556s is provided with an additional isolation unit of live rubber construction and a built-in Cannon Connector.

The true uni-directional characteristics of the Model 556s provide an easy solution to the background noise and feedback problem in reverberant locations, facilitate orchestral placement, permit best utilization of space in small broadcast studios, and provide practically complete exclusion of unwanted noises.



Cannon  
Electric-type  
Connector  
XL-3-11

Model  
556s  
"Small  
Broadcast"

Model 556s "Small Broadcast"  
Code: RUOV List Price \$100.00

Patented by Shure Brothers, Inc.



**SHURE BROTHERS, Inc.** ★

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AND ACOUSTIC DEVICES

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## Industrial Notes

(Continued from page 102A)

### BRITISH RADIO COMPONENT SHOW IN LONDON, APRIL 7-9

The ninth annual private exhibition of British Components, Tubes, and Test Gear, will be held in the Great Hall, Grosvenor House, Park Lane, London, from April 7 through April 9, 1952. Over 100 firms are slated to participate in the show which is designed to inform manufacturers and engineers of the latest advances in the design and development of British radio equipments. Special facilities are planned for the reception and information of manufacturers and agents from abroad, according to the announcement.

### INTERPRETATION OF COLOR ORDER GIVEN

Officials of the National Production Authority have emphasized that the government has no intention of relaxing its ban on mass production of color television equipment (NPA Order M-90, RTMA Industry Report, vol. 7, no. 52). It was explained that the order applies to color TV apparatus for theaters as well as to the use of some types of color tubes in regular black-and-white receivers.

<sup>1</sup> The data on which these *NOTES* are based were selected, by permission, from *Industry Reports* issues of November 23, November 30, and December 7, published by the Radio-Television Manufacturers' Association, whose helpfulness is greatly appreciated.

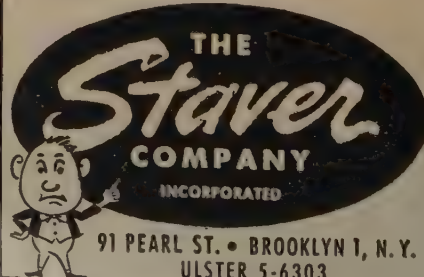
## The New STAYER MINI-SHIELD

U. S. PATENT NO. 2,499,612  
TRADE MARK REGISTERED

The shield  
that fits all  
Miniature  
Tubes



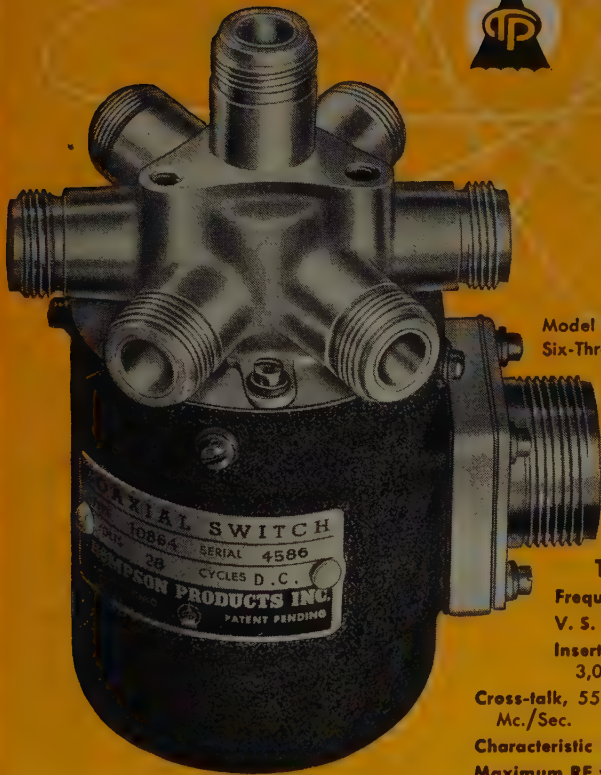
A flexible shield that snugly fits all miniature tubes because it compensates for all variations in tube dimensions. Mini-Shields are made for both T5½ and T6½ bulb tubes. Send for catalog sheet.



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**FOR**

## COAXIAL SWITCHES



Model No. 10864, Single-Pole,  
Six-Throw Coaxial Switch.



Model No. 10565,  
Single-Pole, Two-  
Throw Coaxial Switch.

### TYPICAL PERFORMANCE

Frequency range, 0 to 10,750 Mc./Sec.  
V. S. W. R., 1.5 maximum  
Insertion loss, 0.2 decibels or less at  
3,000 Mc./Sec.

Cross-talk, 55 decibels minimum at 3,000  
Mc./Sec.

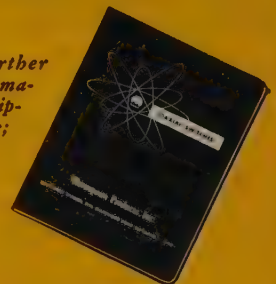
Characteristic impedance, 50 ohms nominal  
Maximum RF voltage, 500 volts, RMS

Power rating, CW Maximum continuous 100  
watts at 3,000 Mc./Sec.

RELIABLE R-F AND MECHANICAL PERFORMANCE under extreme environmental conditions is guaranteed in types which include single-pole, 2-throw, 3-throw, 4-throw and 6-throw; double-pole, double-throw; and Sensing Switches. Remote actuation (28 volts DC or 115 volts AC) is available for all.

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- \* DIRECT READING
- \* COUNTING TO 1,000,000 CPS
- \* RUGGED PLUG-IN CONSTRUCTION

*Berkeley's* complete line of decimal counting units includes the improved Models 700A and 705A, now offering higher counting speeds, increased stability and longer operating life. Two new units, the 706A and 707A, have been added to provide maximum counting rates of 350,000 and 1,000,000 cps respectively. All units are designed for cascade arrangement to provide any desired total count capacity. All units of same model number interchangeable without adjustment. Instantaneous reset to zero through opening of grid return circuit.

### SPECIFICATIONS

	MODEL 700A	MODEL 705A	MODEL 706A	MODEL 707A
Maximum Counting Rate	40,000 cps	100,000 cps	350,000 cps	1,000,000 cps
Resolution—Pulse Pairs	5 $\mu$ sec.	5 $\mu$ sec.	1 $\mu$ sec.	0.8 $\mu$ sec.
Tubes	4-5963	4-5963	4-5963 5-6AL5	4-5687 6-6AL5
Plug-In Mounting	Octal	Octal	11 pin	11 pin
Dimensions	1 $\frac{3}{8}$ "x5 $\frac{1}{2}$ "x5 $\frac{1}{2}$ "	1 $\frac{3}{8}$ "x5 $\frac{1}{2}$ "x5 $\frac{1}{2}$ "	2 $\frac{1}{2}$ "x5 $\frac{1}{2}$ "x5 $\frac{1}{2}$ "	3 $\frac{1}{4}$ "x5 $\frac{1}{2}$ "x5 $\frac{1}{2}$ "
Weight	12 oz.	12 oz.	24 oz.	24 oz.
Price*	\$50	\$60	\$95	\$145

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#### AKRON

"Airbourne Antenna Development," by R. B. Jacques, Thompson Products, Inc.; November 20, 1951.

#### ATLANTA

"Highlights on Overseas Communications," by I. S. Coggeshall, President, Institute of Radio Engineers; October 19, 1951.

Conducted tour of Long Distance telephone building by N. B. Fowler and associates, American Telephone and Telegraph Company; November 16, 1951.

#### BALTIMORE

"Application of Information Theory," by Dr. W. G. Tuller, Melpar, Inc.; December 12, 1951.

#### BEAUMONT-PORT ARTHUR

"Seismograph Field Operations," by L. G. Ellis, Sun Oil Company; December 11, 1951. •

#### BOSTON

"Audio in England," by H. A. Hartley, H. A. Hartley Ltd.; November 6, 1951.

"Characteristics and Applications of Ceramic Dielectrics," by Dr. Leslie Gulton, Gulton Manufacturing Company; November 29, 1951.

#### BUFFALO-NIAGARA

"The RCA Color Television Camera Chain," by J. D. Spradlin, RCA Victor Division; November 21, 1951.

#### CHICAGO

"Fixed-Length Transmission Lines as Tunable Circuit Elements," by A. A. Meyeshoff and Robert Graham, Jr., Coles Signal Laboratory; "Reliability of Tubes," by R. E. Moe, General Electric Company; and "Limitations of an FM Signal Generator," by Leonard Mayberry, Hallicrafters Company; October 19, 1951.

"Carrier and Microwave Radio Applications to Power Systems," by R. C. Cheek, Westinghouse Electric Corporation; "A New Magnetic Recording Head," by Marvin Camras, Armour Research Foundation; "A Phase Meter Covering Wide Frequency Range," by H. L. Gray; and "Impedance Discontinuities in Beaded Coaxial Lines," by John Brown, Andrew Corporation; November 16, 1951.

#### CLEVELAND

"UHF High Power Klystron Transmitter and Helical Antennas," by H. G. Towilson, General Electric Company; November 15, 1951.

#### COLUMBUS

"Research Trends in Engineering Psychology," by Dr. P. M. Fitts, Faculty, Ohio State University; December 6, 1951.

#### CONNECTICUT VALLEY

"Cosmic Ray Measurements in the Upper Atmosphere," by Dr. S. A. Korff, Faculty, New York University; November 15, 1951.

#### DES MOINES-AMES

"The Westinghouse 50-HG-2 Transmitter," by Reed Snyder, Radio Station WHO; November 20, 1951.

"The Theory of Operation of the Vacuum Tube Oscillator," by W. L. Cassell, Faculty, Iowa State College; December 6, 1951.

#### DETROIT

"New Worlds with the Electron Microscope," by Dr. D. M. Teague, Chrysler Corporation; November 16, 1951.

(Continued on page 108A)



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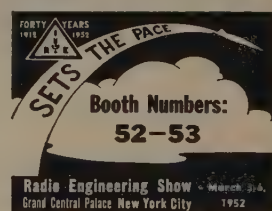
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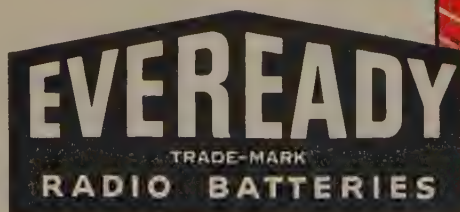
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(Continued from page 106A)

### EMPORIUM

"Subminiaturization and its Contribution to Reliability," by J. G. Reed, National Bureau of Standards; and "Aspects of Subminiaturization," by John Dawson, Sylvania Electric Products Inc.; August 17, 1951.

"Reliability Symposium; August 18, 1951.

"Electronics in Medicine," by Nathan Marchand; September 18, 1951.

"Electrical Measuring Instruments—Their Construction, Operation and Selection," by R. J. Teetsel, Westinghouse Electric Corporation; November 6, 1951.

### EVANSVILLE-OWENSBORO

"WSM Microwave Relay from Louisville to Nashville," by John DeWitt, WSM; November 14, 1951.

"Future Trends of Industrial Television," by M. C. Banca, Industrial Television Radio Corporation of America; December 11, 1951.

### FORT WAYNE

"Manufacturing Processes in Television Tube Production," by J. J. O'Callaghan, The Rauland Corporation; December 6, 1951.

### LOS ANGELES

"The RCA Color Television Camera Chain," written by J. D. Spradlin and read by A. N. Curtis; "Graphecon Technique in Bright-tube Radar Displays," written by L. M. Seeberger and read by F. J. Sommers; and "Patents of the Engineer," by Irl Goshaw; December 4, 1951.

### LOUISVILLE

"Industrial Electronic Heating," by T. L. Wilson, Thermex Division of Girdler Corporation; December 14, 1951.

### NEW YORK

"Measuring Noise Color," by J. W. Tukey, Bell Telephone Laboratories, Inc.; November 7, 1951.

### NORTH CAROLINA-VIRGINIA

"Electronics in Atomic Energy," by Dr. L. A. Pardue, Virginia Polytechnic Institute; November 30, 1951.

### OMAHA-LINCOLN

"Magnetic Amplifiers," by J. G. Miles, Engineering Research Associates; November 14, 1951.

"Digital Computers as Information Processing Systems," by W. C. Robison and C. W. Rook, Faculty, University of Nebraska; December 10, 1951.

### OTTAWA

"Some Mathematical Aspects of Circuit Analysis," by Prof. H. G. I. Watson, Faculty, McGill University; November 22, 1951.

### PHOENIX

"Application of Quality Control Techniques to Electronic Apparatus and Equipment," by Dr. H. G. Romig, Hughes Aircraft Company; November 16, 1951.

### PITTSBURGH

"Microwave Shoran," by Mr. Alexander, Gulf Research Laboratories; September 10, 1951.

"Recent Developments in Transistors," by J. A. Morton, Bell Telephone Laboratories, Inc.; October 15, 1951.

"Recent Developments in Automatic Train Control," by L. R. Allison, Union Switch and Signal; November 12, 1951.

"Ultrasonics," by Dr. P. Conley, Westinghouse Research Laboratories; December 16, 1951.

(Continued on page 110A)

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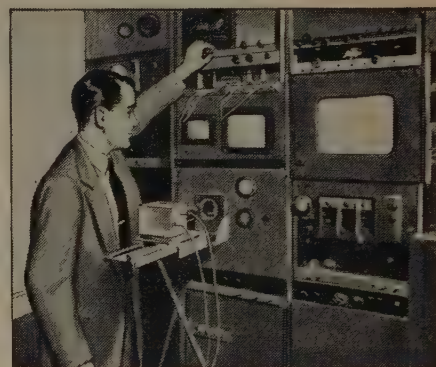
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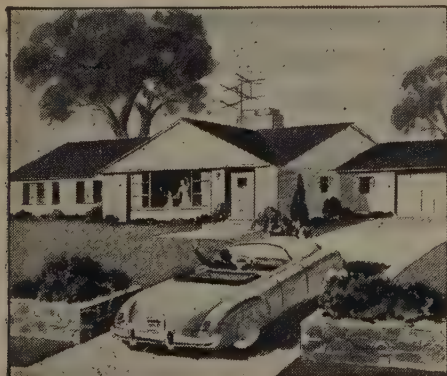
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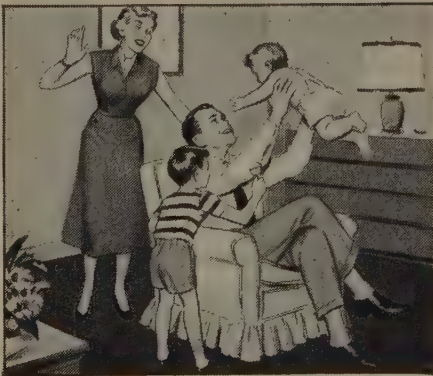
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### PRINCETON

"Atoms and Molecules as High-A Microwave Resonators," by R. H. Dicke, Faculty, Princeton University; December 6, 1951.

### ST. LOUIS

"Development and Testing of Guided Missiles," by G. J. Fiedler, Sverdrup & Parcel; November 29, 1951.

### SALT LAKE CITY

"Meteor Study by Radio," by M. E. Van Valkenburg, Faculty, University of Utah and "The TV Camera," by Walter Davis, Jr., Station KSL-TV; November 19, 1951.

### SAN ANTONIO

"Bell System Television Networks," by Dr. M. E. Strieby, American Telephone and Telegraph Company; October 31, 1951.

"Highlights of Overseas Communications," by I. S. Coggeshall, President, Institute of Radio Engineers; November 14, 1951.

### SAN DIEGO

"Executive vs. Scientist," was J. P. Maxfield, U. S. Navy Electronics Laboratory; December 4, 1951.

### SAN FRANCISCO

"A New Type of Low Frequency Generator," by Robert Brunner, Hewlett-Packard Company; September 5, 1951.

"Color Television," by A. G. Jensen, Bell Telephone Laboratories, Inc.; October 23, 1951.

### SEATTLE

"Electronic Trends of Tomorrow," by Dr. J. D. Ryder, Faculty, University of Illinois; September 21, 1951.

"A Single Ended Push-Pull Amplifier," by Dr. A. Peterson, General Radio Company; October 11, 1951.

"System Principles in Color Television," by D. E. Foster, Hareline Research Inc. of California; November 16, 1951.

### SYRACUSE

"Instrumentation in High Energy Nuclear Physics," by Dr. R. M. Littauer, Faculty, Cornell University; November 1, 1951.

### TORONTO

"Some Experiments with 850 Megacycle Television Transmissions Using Beam-Tilting Antennas," by Dr. G. H. Brown, RCA Laboratories Division; December 3, 1951.

### WASHINGTON, D. C.

"Recent Trends in Long Range Radio Communications," by M. G. Crosby, The Crosby Laboratories, Inc.; November 12, 1951.

### WILLIAMSPORT

"The Transistor," by Dr. Angello, Westinghouse Electric Corporation; December 12, 1951.

### SUBSECTIONS

#### LANCASTER

"Sub-Miniaturization," by Dr. W. G. Tuller, Melpar, Inc.; November 14, 1951.

#### LONG ISLAND

"Focusing Sound Waves with Microwave Lenses," by F. K. Harvey, Bell Telephone Laboratories, Inc.; November 13, 1951.

#### NORTHERN NEW JERSEY

"Recent Trends in Long-Range Communications," by M. G. Crosby, Crosby Laboratories, Inc.; November 14, 1951.



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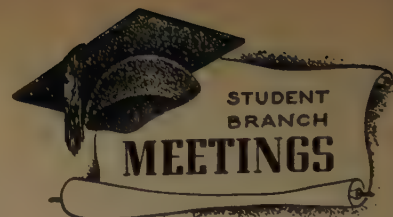
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GEORGIA INSTITUTE OF TECHNOLOGY, IRE BRANCH  
"Problems of Electrical Engineering in High Energy Accelerators," by M. R. Donaldson, Oak Ridge, Tenn.; November 27, 1951.

STATE UNIVERSITY OF IOWA, IRE BRANCH

"Practical Experience with the Signal Corps," by William Carr and "Iowa City Speed Analyzer," by M. D. Goodrich, Students, State University of Iowa; October 24, 1951.

"Cruise Ship Electrical; System," by Roger Sherman and "Electric Shock First Aid," by Delmar Lanphere, Students, State University of Iowa; November 14, 1951.

"The Collins Radio Company and Its Engineering Opportunities," by R. T. Cox; November 28, 1951.

UNIVERSITY OF LOUISVILLE, IRE BRANCH

Film, "RCA's Ultrafax"; November 27, 1951.

MANHATTAN COLLEGE, IRE-AIEE BRANCH

"The Television Receiver," by George Fuchs, Student, Manhattan College; November 14, 1951.

"Magnetic Amplifiers," by Mr. Dornhoefer, Industrial Regulator Corporation; November 28, 1951.

MARQUETTE UNIVERSITY, IRE-AIEE BRANCH

Election of officers and general meeting; October 25, 1951.

Field trip through Cutler-Hammer; November 1, 1951.

General meeting; November 8, 1951.

UNIVERSITY OF MARYLAND, IRE-AIEE BRANCH

"Rocket Experiment in Regard to the Upper Atmosphere," by H. E. Nowell, Naval Research Laboratories; December 5, 1951.

UNIVERSITY OF MICHIGAN, IRE-AIEE BRANCH

"The Electrical Properties of Silicone," by G. E. MacIntyre, Dow-Corning Corporation; November 19, 1951.

UNIVERSITY OF MINNESOTA, IRE-AIEE BRANCH

"Engineering Problems and You," by H. E. Hartig, Faculty, University of Minnesota; October 17, 1951.

Business meeting and demonstration of equipment by Alfred Crossley & Associates of Chicago; October 31, 1951.

UNIVERSITY OF MISSOURI, IRE-AIEE BRANCH

"If I Were You," by J. D. Hoffman, Kearney Electric Company; November 16, 1951.

NEW YORK UNIVERSITY (DAY DIV.), IRE BRANCH

"Network Topology," by C. F. Rehberg, Faculty, New York University; November 1, 1951.

"Switching Circuits," by B. J. Ley, Faculty, New York University; November 8, 1951.

"Radar Demonstration" by Mr. Clausius, Bell Telephone Laboratories, Inc.; November 15, 1951.

NORTHEASTERN UNIVERSITY, IRE-AIEE BRANCH

"Recent Developments in Radio Communications," by W. H. Radford, Faculty, Massachusetts Institute of Technology; October 23, 1951.

"This is a Woman's World," by W. J. Pinard, Faculty, Boston University; November 1, 1951.

"Industrial Instruments," by J. L. Hayden, Foxboro Company; November 8, 1951.

"Speech Analysis," by Richard Tilley, Student, Northeastern University; November 30, 1951.

(Continued on page 118A)

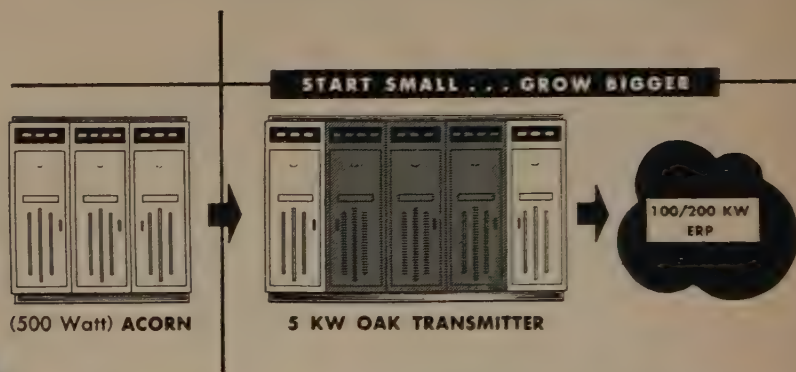
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(Continued from page 114A)

Film, "Exploring with X-Rays"; December 6, 1951.

"Introduction to Microwaves," by J. Kline, Raytheon Manufacturing Company; December 13, 1951.

**OHIO STATE UNIVERSITY, IRE-AIEE BRANCH**

"History of Electrical Engineering Department," by F. C. Caldwell, First Chairman, Electrical Engineering Department, Ohio State University; October 25, 1951.

**OKLAHOMA AGRICULTURAL & MECHANICAL COLLEGE, IRE-AIEE BRANCH**

"The Instrument Story," by Henry Berring, Weston Electrical Instrument Corporation; December 5, 1951.

**PRATT INSTITUTE, IRE BRANCH**

Election of officers; November 14, 1951.  
Talk by Mr. Schmidt, RCA Victor Div.; November 28, 1951.

"Transformers," by R. E. Uptegraft, R. E. Uptegraft Company; December 12, 1951.

**PRINCETON UNIVERSITY, IRE-AIEE BRANCH**

"Color Television," by F. J. Bingley, Philco Corporation; November 29, 1951.

Guided tour of Bell Telephone Overseas Transmitter Station; December 13, 1951.

**RENSSELAER POLYTECHNIC INSTITUTE, IRE-AIEE BRANCH**

"Evolution of a Substation," by Jack Lewis, Connecticut Power Company; November 13, 1951.

**UNIVERSITY OF RHODE ISLAND, IRE-AIEE BRANCH**

Films, "Electronics at Work," and "Electrical Proving Grounds"; December 6, 1951.

**RUTGERS UNIVERSITY, IRE-AIEE BRANCH**

Film, "D. C. Commutation," Student papers, and talk by P. S. Creager, Faculty, Rutgers University; November 13, 1951.

"Microwave Relay Equipment," by Spencer Ross, Philco Corporation; November 27, 1951.

**SAN DIEGO STATE COLLEGE, IRE BRANCH**

Field trip to KECA-TV; November 30, 1951.  
"Transducers and their Properties," by Jeff Gould, Naval Electronics Laboratories; December 6, 1951.

**UNIVERSITY OF SYRACUSE, IRE-AIEE BRANCH**

"Color Television," by I. C. Abrams, General Electric Company; November 8, 1951.

**UNIVERSITY OF TEXAS, IRE-AIEE BRANCH**

General meeting; November 19, 1951.  
"Aftermath of the British Elections," by W. S. Livingston, Faculty, University of Texas, December 3, 1951.

**TUFTS COLLEGE, IRE-AIEE BRANCH**

Field trip of WBZ-TV by Mr. Hauser, Technical Supervisor; November 29, 1951.

**UNIVERSITY OF VIRGINIA, IRE BRANCH**

"Electrical Indicating Instruments," by Henry Berring, Weston Electrical Instrument Corporation; October 18, 1951.

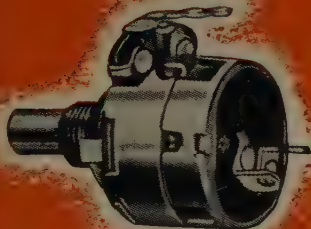
"Capacitors," by M. Kimbrell, General Electric Company and "Resistivity of the Skin," by Charles Barnes, Student, University of Virginia; November 5, 1951.

(Continued on page 122A)

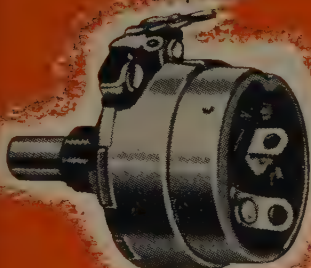
# Meets Military Specifications



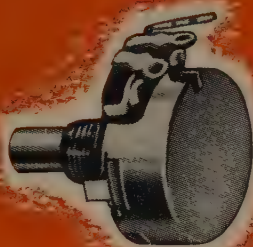
JAN-R-94, Type RV-3A  
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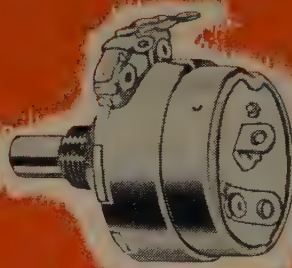
JAN-R-94, Type RV-2B  
CTS Type GC 45 with Switch  
Composition



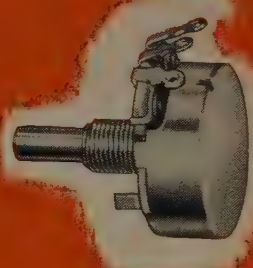
JAN-R-94, Type RV-3B  
CTS Type GC 35 with Switch  
Composition



JAN-R-94, Type RV-2A  
CTS Type 45, 1 5/16" Diameter  
Composition

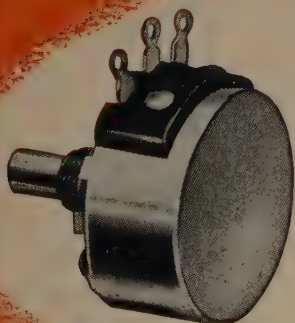


JAN Type RV-4B  
CTS Type FGC 95 with Switch  
Composition

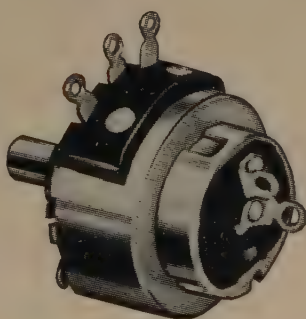


JAN Type RV-4A  
CTS Type 95, 1 1/8" Diameter  
Composition

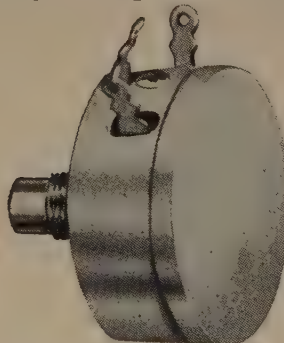
## MEETS ALL JAN-R-19 SPECIFICATIONS



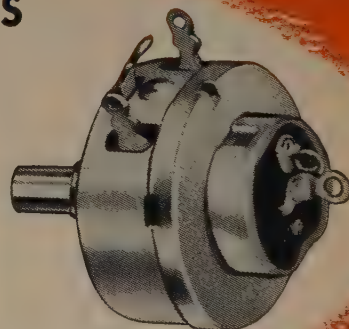
JAN Type RA 20A  
2 Watt (CTS Type 252)



JAN Type RA 20B  
2 Watt (CTS Type GC-252)



JAN Type RA 25A or 30A  
3 or 4 Watt (CTS Type 25)



JAN Type RA 25B or 30B  
3 or 4 Watt (CTS Type GC 25)

EXCEPTIONALLY GOOD DELIVERY CYCLE  
on military orders due to enormous mass  
production facilities . . . Please give complete  
details on your requirements when writing  
or phoning for further information.



CHICAGO TELEPHONE SUPPLY  
*Corporation*

FOUNDED 1896

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### REPRESENTATIVES

Henry E. Sanders  
401 North Broad Street  
Philadelphia 8, Pennsylvania  
Phone: Walnut 2-5369

W. S. Harmon Company  
1638 So. La Cienega Blvd.  
Los Angeles 35, California  
Phone: Broadshaw 2-3321

### IN CANADA

C. C. Meredith & Co.  
Streetsville, Ontario

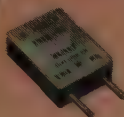
### SOUTH AMERICA

Jose Luis Pontel  
Buenos Aires, Argentina  
Montevideo, Uruguay  
Rio de Janeiro, Brazil  
Sao Paulo, Brazil

### OTHER EXPORT

Sylvan Ginsbury  
8 West 40th Street  
New York 18, N. Y.

# it's Craftsmanship



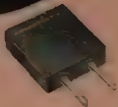
**TYPE MC9 RANGE:**  
1.0 - 10.0 mc  
Supplied per Mil type  
CR-3 CR-6 CR-8;  
CR-10 when specified.



**TYPE AR23W RANGE:**  
0.080 - 0.19999 mc  
Supplied per Mil type  
CR-15; CR-16; CR-29;  
CR-30 when specified.



**TYPE BH6A RANGE:**  
1.4 - 75.0 mc  
Supplied per Mil type  
CR-18; CR-19; CR-23;  
CR-27; CR-28; CR-32;  
CR-33; CR-35; CR-36  
when specified.



**TYPE SR5A RANGE:**  
2.0 - 15.0 mc  
Supplied per Mil type  
CR-1A when specified.



**TYPE TCO-1**  
Temperature Control  
Oven.



**TYPE BH7A RANGE:**  
15.0 - 50.0 mc  
Supplied per Mil type  
CR-24 when specified.

## Bliley CRYSTALS

**BLILEY ELECTRIC COMPANY**  
UNION STATION BUILDING  
ERIE, PENNSYLVANIA

**Craftsmanship** shows up when the going gets roughest. You can't see it but it's there—in every Bliley crystal. Such basic quality ingredients as precision and stability depend upon *craftsmanship*. When you buy Bliley you get this extra assurance that can only be supplied by experience.

# STUDENT BRANCH MEETINGS

(Continued from page 118A)

"Graduate Study in Industry," by John Gammell, Allis-Chalmers and "Television Problems in the Shenandoah Valley," by Bob Humphris, Student, University of Virginia; December 11, 1951.

UNIVERSITY OF WASHINGTON, IRE-AIEE BRANCH  
"Electronic Aids to Air Navigation," by Glen Mains, Seattle-Tacoma Airport; November 1, 1951.

YALE UNIVERSITY, IRE-AIEE BRANCH  
"The Auto-Pilot—Its History and Operation," by Percy Halpert, Sperry Engineering; November 28, 1951.

## What to see at the Radio Engineering Show

(Continued from page 95A)

**Firm** **Booth**  
Hickock Elec. Instr. Co., Cleveland 8, Ohio **N-11**  
Signal generators, oscilloscopes, volt ohm milliammeters, tube testers, vacuum tube volt meters, indicating instruments, both portable, panel, and switchboard type.

**High Fidelity Magazine**, Great Barrington, Mass. **325**  
A magazine devoted to the use of radio, TV, records and tape for home musical entertainment. An audio hobbyists magazine.

**Hytron Radio & Electronics Corp.**, Salem, Mass. **23, 24**  
Radio receiving tubes, television receiving tubes, cathode-ray tubes, transmitting tubes, special purpose tubes.

**Illinois Condenser Co.**, Chicago 22, Ill. **469**  
Fixed capacitors, electrolytic types, hermetically sealed electrolytics.

**Indiana Steel Products Co.**, Valparaiso, Ind. **278**  
Alnico permanent magnets, Cunife permanent magnets, steel permanent magnets, ion traps, and radar magnets.

**Industrial Products Co.**, Danbury, Conn. **225**  
Connectors and rf components.

**Industrial Hardware Mfg. Co.**, Philadelphia, Pa. **410**  
See: Eby, H. H.

**Industrial Timer Corp.** **221**  
See: Wally Swank

**Industrial Tape Corp.**, New Brunswick, N.J. **491**  
Pressure sensitive electrical adhesive tapes.

**Instrument Specialties Co., Inc.**, Little Falls, N.J. **261**  
Beryllium copper coil and flat springs, beryllium copper component parts for radio and electronic equipment.

**Instruments Publishing Co.**, Pittsburgh 12, Pa. **S-14**  
*Instruments. The Instrument Maker, The Instrument Maker Guide, The Instrument Index, The Handbook of Measurement & Control*, and other books on various phases of instrumentation design, theory and application.

**Insuline Corp. of America**, Long Island City 1, N.Y. **239**  
Electronic components, sheet metal fabrications and assemblies for electronic housings, special purpose antennas.

**International Nickel Co., Inc.**, New York 3, N.Y. **35**  
Nickel-clad steel strip and wire for vacuum tube parts (new material being experimented with as substitute at present for nickel in vacuum tube uses.) Various high nickel alloy components used in aircraft electronic parts and in jet planes generally.

(Continued on page 124A)

# Check up CHECK OUT



## WITH SIGNAL GENERATORS

by  
**AIRCRAFT RADIO Corporation**

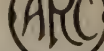


### TYPE H-14 108-132 MEGACYCLES

Standard signal source for complete testing of VHF airborne omnirange and localizer receivers in aircraft or on the bench is ARC's Type H-14 Signal Generator. It checks up to 24 omni courses, omni course sensitivity, to-from and flag-alarm operation, left-center-right on 90/150 cycle and phase-localizers, and all necessary quantitative bench tests. Permits quick, accurate, check-out of aircraft just before take-off. For ramp checks RF output 1 volt into 52 ohm line; for bench checks, 0-10,000 microvolts. AF output available for bench maintenance and trouble shooting.

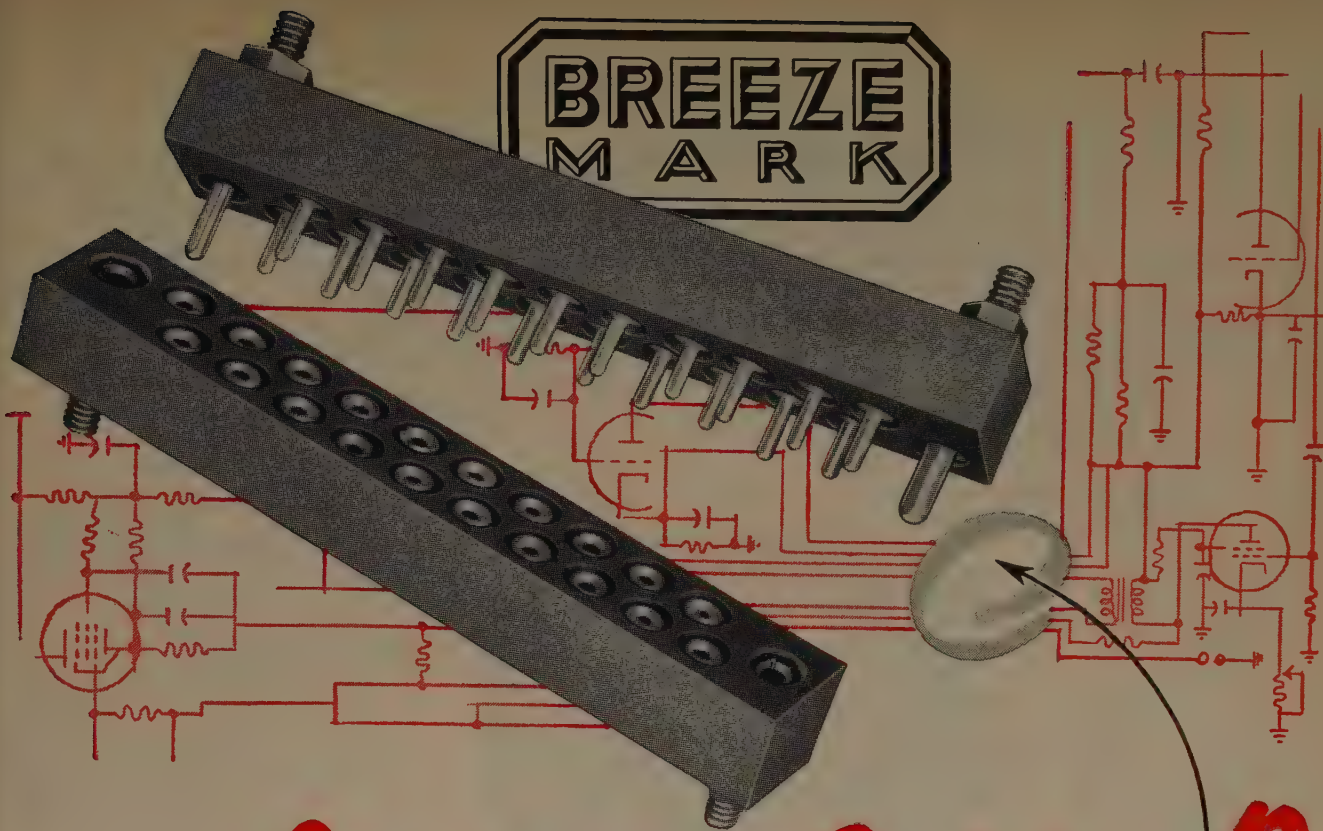
Price \$885.00 net, f.o.b. Boonton, N.J.

**Type H-12 VHF Signal Generator** 900 - 2100 mc—source of cw or pulse amplitude-modulated RF. Power level 0 to -120 dbm. Internal pulse circuits with controls for width, delay, and rate, and provision for external pulsing. Frequency calibration better than 1%. Built to Navy specs for research, production testing. Equal to Military TS-419/U.



Price: \$1,950.00 net  
f.o.b. Boonton, N.J.

**AIRCRAFT RADIO CORPORATION**  
Boonton New Jersey  
Dependable Electronic Equipment Since 1928

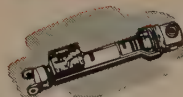


# Connector Problem?

...We'll take it from **HERE**

Good ideas for electronic circuitry sometimes run afoul of connector problems. Maybe existing connector units won't hold air pressure gradients, won't stand the heat, aren't rugged enough for the job. Or maybe it's a question of altitude, or under-water application. But if you can sketch the circuit, we'll take it from there. We've engineered so many special connectors, solved so many "impossible" problems, that whatever the requirements are, we can usually provide the answer.

**WRITE TODAY** for specific information, or send us your sketches. We'll forward recommendations promptly.



Lightweight actuators for any requirement.



Job engineered, welded diaphragm bellows.



Flexible conduit and ignition assemblies.



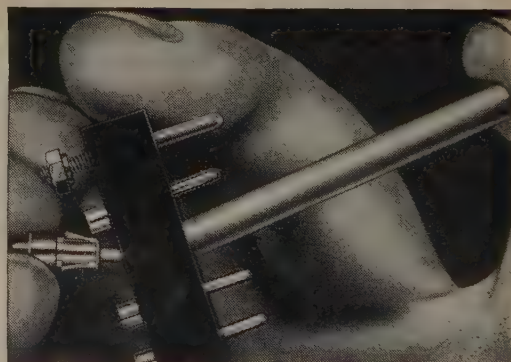
Aero-Seal vibration-proof hose clamps.

## **BREEZE** Special CONNECTORS

**BREEZE CORPORATIONS, INC.**

41 South Sixth Street

Newark, New Jersey

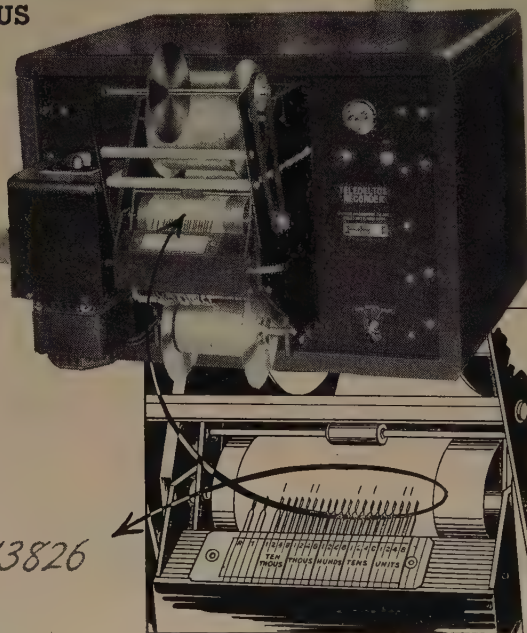


Removable pins in Breeze connectors speed soldering, save time, trouble. Pins snap back into block.

(Continued from page 122A)

NOW...9000 records  
per minute!  
with the NEW POTTER high speed  
**TELEDELTO  
RECORDER**

IMMEDIATELY VISIBLE  
INSTANTANEOUS  
PERMANENT  
DIGITAL



Designed to record measurements obtained on Potter Electronic counters, scalars, chronographs and frequency-time counters.

The Potter Instrument Co. High Speed Teledelto Recorder provides a permanent recording of digital information at rates up to 150 six-digit answers per second. The measurements are transferred to electrically sensitive paper using four styli for each digit arranged in the famous Potter (1-2-4-8) read-out. The records are indexed intermittently and controlled by the events being measured.

Write for information on specific applications to Dept. 5T.

See Us in Booth No. 109

**POTTER RECORDING  
COUNTER CHRONOGRAPH**

Measures time intervals up to 0.10000 second in increments of 2.5 microseconds. (Higher resolutions are also available.) Applicable to projectile velocity measurements, frequency measurements, geophysical measurements, telemetering and wherever micro-second timing is required.



**POTTER INSTRUMENT COMPANY**

INCORPORATED  
115 CUTTER MILL ROAD, GREAT NECK, NEW YORK



**Firm** **Booth**  
**International Resistance Co., Philadelphia**  
8, Pa. 102  
Standard line of resistors, plus Boron Carbon resistors, Miniature selenium rectifiers, hermetic seal terminals.

**J-B-T Instruments, Inc., New Haven 8, Conn.** N-20  
Vibrating reed frequency meters, including 1 1/2" and 3/4" sealed types and 60-400 cps types for audio-oscillators; AC elapsed time meters; 14 and 20 position rotary selector switches, molded and laminated types; lever switches, 2, 3, and 4 position types; pyrometers, resistance thermometers, and other temperature measuring instruments; and 2" ac and dc electrical panel meters made by subsidiary, Shurite meters.

**JFD Manufacturing Co., Inc., Brooklyn 4, N.Y.** 215  
TV antennas, boosters, TV set couplers, TV voltage regulators, lightning arresters, indoor TV antennas, TV aligning tools, TV mounts, TV ballasts, TV wave traps, and filters, TV screw eye standoffs.

**Jeffers Electronics, Inc., Du Bois, Pa.** 432  
Ceramic Capacitors: H V, tubular, disk, feed thru, stand off. Plain and molded rf choke coils: Universal and solenoid. Trimmers, combined resistors and capacitors, low value capacitors.

**Jensen Mfg. Co., Chicago 38, Ill.** 312  
Loudspeakers, horns, cabinets, transformers, associated acoustic equipment.

**Howard B. Jones Div., Cinch Mfg. Corp., Chicago 24, Ill.** 255, 256  
Electrical connecting devices.

**Kalbfell Labs., Inc., San Diego 10, Calif.** 264, 265  
Micro-Miker (an instrument for measuring small capacitances). Ratio voltmeter, servo-stabilizer, Twin-T filters, peaked amplifiers, Logatens, and logarithmic amplifier system.

**Karp Metal Products Co., Inc., Brooklyn 20, N.Y.** 49, 50  
Sheet metal consoles, cabinets, enclosures and housings for electronic, electrical, and mechanical equipments.

**Kay Electric Co., Pine Brook, N.J.** 22  
Calibrated Mega-sweep, mega-X, Kilo-Sweep, Sona-Sweep, model video Marka-Sweep, model RFP Marka-Sweep, model uhf Mega-Match, Mega-Node, Mega-Node, Sr., microwave Mega-Nodes, Mega-Pulser, Micro-Pulser, Vibralyzer, Sona-Stretcher Rada-Sweep, Megaligner. Models 20 and 21 attenuators, Rada-Pulser and Stablohm carbon film resistors, Model WB Rotalyzer.

**Kenyon Transformer Co., Inc., New York 59, N.Y.** 56  
Transformers and reactors.

**Kepco Laboratories, Inc., Flushing, L.I., N.Y.** 359A  
DC voltage regulated power supplies—16 different models. Low voltage—high and low current. Medium voltage—high and low current. High voltage—high and low current. Kepco super regulated power supplies (dc power regulated to 0.01%).

**Kester Solder Co., Chicago 39, Ill.** 252  
Solders and soldering fluxes and soldering accessories.

**Ketay Manufacturing Corp., New York 12, N.Y.** 329  
Synchros, resolvers, and various control instruments.

**Kings Electronics Co., Inc., Tuckahoe 7, N.Y.** 291  
Coaxial connectors, rf fittings, microwave assemblies, wave guide components, and antennas.

**James Knights Co., Sandwich 1, Ill.** S-15  
Quartz oscillator crystals; quartz filter crystals; quartz ultrasonic crystals; quartz crystal blanks, all sizes and shapes; miniature crystal ovens; Large temperature stabilizers; broadcast ovens; frequency standards; JK (Doolittle) Frequency monitors, Crystal holders, and associated equipment.

(Continued on page 126A)



# PANORAMIC

RADIO PRODUCTS, INC.

## SETS THE PACE

# IN SPECTRUM ANALYSIS

## FROM AUDIO TO MICROWAVE FREQUENCIES

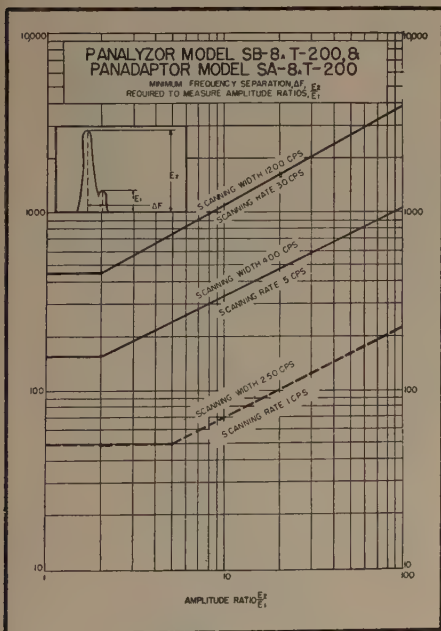


More Valuable Than Ever!

### PANADAPTOR SA-8a ANALYZOR SB-8a

New Panoramic engineering achievements embodied in these improved instruments open important new applications involving modulation and interference problems.

- IMPROVED RESOLUTION DOWN TO 50 CPS FOR RF spectrum analysis where maximum resolution is a "must"
- LOW SWEEP RATES DOWN TO 1 SCAN PER SECOND for analysis of pulsed RF signals with low p.r.f.'s
- LONG PERSISTENCE DISPLAYS
- CONTINUOUSLY VARIABLE SCANNING WIDTH



# PANORAMIC

RADIO PRODUCTS, INC.

Collect data more quickly and easily with Panoramic's graphic assistance. You will find that these fine instruments are unexcelled for laboratory, research and production applications requiring spectrum or waveform analysis.

Whatever your problem—there is a Panoramic analyzer to answer your needs for analyzing waveform distortions, noises, characteristics of AM, FM or pulsed signals, vibrations, spurious oscillations or modulation, response characteristics of filters or transmission lines or monitoring many frequency channels simultaneously.

#### PANORAMIC SONIC ANALYZER, MODEL LP-1 for increased harmonic resolution in high speed audio waveform analysis.

20 KC log scale provides a complete visual spectrograph of the sonic spectrum from 40 to 20,000 cps. A tuning control and a three-step scanning range selector permit selection and magnification of any spectrum segment for sharp, detailed analysis.

3 Selectable Linear Scanning Ranges  
Pre-Adjusted Optimum Resolution

Scanning Range	Resolution
100 cps	26 cps
500 cps	53 cps
1500 cps	105 cps



#### PANORAMIC ULTRASONIC ANALYZER, MODEL SB-7 Direct Reading Spectrum Analyzer

Invaluable for channel monitoring, telemetering, medical studies; for investigating ultra audible noises and vibrations. SB-7 allows overall observation of 200KC wide band or highly detailed examination of selected narrow bands.

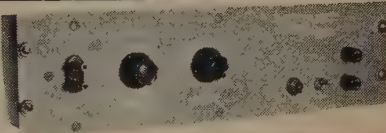
- Frequency Range: 2KC-300KC, linear scale
- Scanning Width: Continuously variable 200KC to zero
- Amplitude Scale: Linear and two decade log
- Input Voltage Range: 500uV-50V
- Resolution: Continuously variable from 2KC to better than 500 cps



#### PANORAMIC SONIC RESPONSE INDICATOR G-2 for More Accurate Frequency Response Measurement

Used with Models AP-1 or LP-1, the G-2 allows visual inspection of the amplitude vs. frequency characteristic of systems in the range between 40 and 20,000 cps. May be used for research, production line testing, etc.

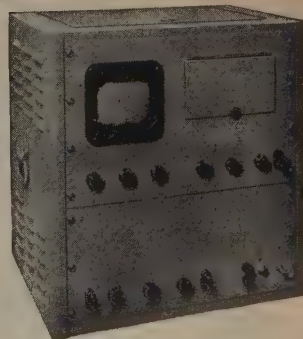
- Linear or log (60 db range) amplitude scale
- Slow, 1 cps sweep rate
- 10-step attenuator with 100 db range selects output voltages between 5 microvolts and 5 volts
- 3 selectable output impedances; 100 ohms, 500 ohms; 3000 ohms



#### PANORAMIC SONIC ANALYZER, MODEL AP-1 Automatic Waveform Analysis in Only 1 Second

Here is your answer for truly simple high speed analysis of vibrations, harmonics, noises, acoustics and intermodulation under static or dynamic conditions. The AP-1 automatically separates and measures frequency and magnitude of complex audio wave components.

Frequency Range	40-20,000 cps, log scale
Input Voltage Range	500uV-500V
Voltage Scale	Linear and two decade log
Resolution	Optimum throughout frequency range



12 SOUTH SECOND AVENUE, MOUNT VERNON, NEW YORK

WRITE TODAY FOR COMPLETE SPECIFICATIONS AND PRICES.

SEE THE COMPLETE LINE OF PANORAMIC INSTRUMENTS DYNAMICALLY DEMONSTRATED AT THE IRE SHOW • Booth N-6.



Vertical Sensitivity  
.018 RMS v.p.i.

Stable Band Width  
Thru 4.5 Mc

# JACKSON Oscilloscope gives you "dual service"

This is a high-quality, laboratory-grade 5" Oscilloscope that provides the "dual service" of both high sensitivity and wide band width.

## s p e c i f i c a t i o n s

**Vertical Amplifier**—Video-type frequency compensation provides flat response within 1.5 db from 20 cycles thru 4.5 Mc, dropping smoothly to a still useful value at 6 Mc.

**Sensitivity Ranges**—With a band width of 20 cycles thru 100 Kc, the sensitivity ranges are .018, .18, 1.8 RMS volts-per-inch. The wide band position 20 cycles thru 4.5 Mc has sensitivity ranges of .25, 2.5, 25 RMS volts-per-inch.

**Horizontal Amplifier**—Push-pull with sensitivity of .55 RMS volts-per-inch.

**Input Impedances**—Vertical: 1.5 megohms shunted by 20 mmfd. Direct to plates, balanced 6 megohms shunted by 11 mmfd. Horizontal: 1.1 megohms.

**Linear Sweep Oscillator**—Saw tooth wave, 20 cycles to 50 Kc in 5 steps. 60 cycle sine wave also available, as well as provision for using external sweep.

**Input Voltage Calibration**—Provides a standard voltage against which to measure

voltages of signal applied to vertical input.

**Vertical Polarity Reversal**—For reversing polarity of voltage being checked or for choosing either positive or negative sync. voltages.

**Return Trace Blanking**—Electronic blanking provides clear, sharp trace to prevent confusion in waveform analysis.

**Synchronizing Input Control**—To choose among INTERNAL, EXTERNAL, 60 CYCLE, or 120 CYCLE positions.

**Intensity Modulation**—60 cycle internal or provision for external voltage for intensity modulation uses.

**Additional Features**—Removable calibration screen—Accessory Model CR-P Demodulation Probe for Signal Tracing—All-steel, gray Ham-R-Tex cabinet. Total net weight only 26 pounds. Same height as other Jackson TV instruments: 13" H x 10 1/4" W x 15 1/8" D.

**Prices:** Model CRO-2, Users' Net \$197.50. Model CR-P Probe, Users' Net \$9.95.

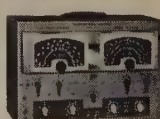
### TWO OTHER FINE JACKSON INSTRUMENTS

#### Model 655 Audio Oscillator



Sine-wave 20 cycles to 200,000 cycles. Less than 5% harmonic distortion between 30 cycles and 15,000 cycles. Frequency calibration accurate within 3% or 1 cycle. Hum level down more than 60 db of maximum power output. Output impedances of 10, 250, 500, 5000 ohms or Hi Z resistive output.

#### Model TVG-2 TV Generator



Sweep Oscillator in three ranges from 2 Mc thru 216 Mc, all on fundamentals. Reversible sweep direction. Sweep width variable 1 Mc thru 18 Mc. Marker covers 4 Mc thru 216 Mc. Crystal Oscillator to use as Marker or Calibrator. Video Modulation, from external source for using actual video signal for check, or for use with Audio Oscillator to produce bars for linearity checks.

See your electronics distributor for more information, or write

**JACKSON ELECTRICAL INSTRUMENT CO. • DAYTON 2, OHIO**

"Service Engineered" Test Equipment  
IN CANADA: THE CANADIAN MARCONI CO.

## What to see at the Radio Engineering Show

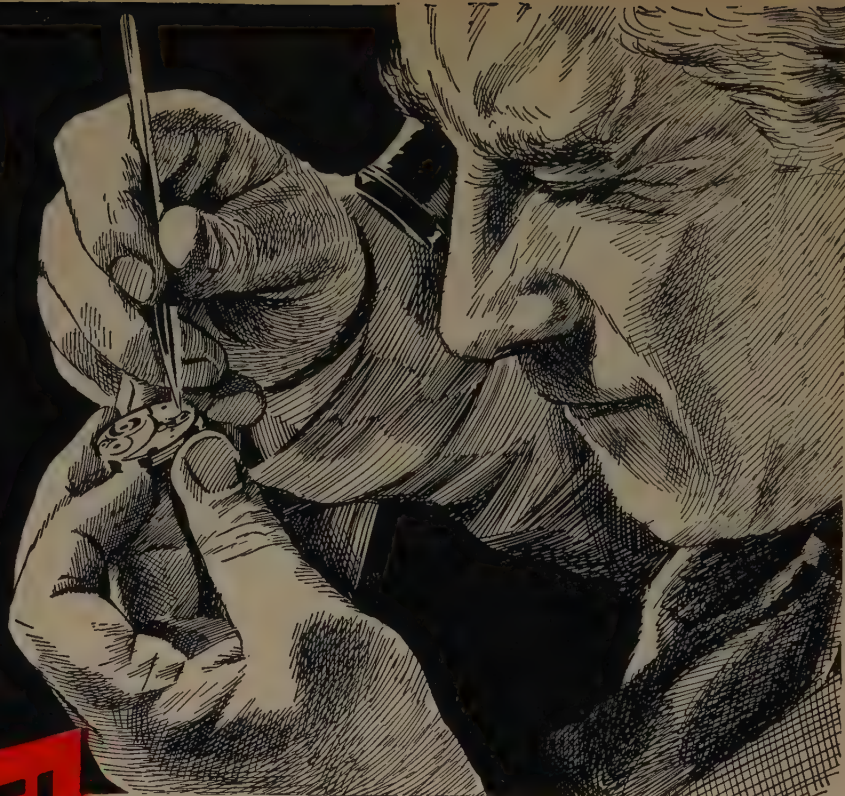
(Continued from page 124A)

- |  |                 |
|--|-----------------|
| <b>Firm</b>  | <b>Booth</b>    |
| <b>Krohn-Hite Instrument Co., Cambridge 39, Mass.</b>  | <b>440</b>      |
| Test and measuring equipment.  |                 |
| <b>Kulka Electric Mfg. Co., Inc., Mt. Vernon, N.Y.</b>   | <b>S-20</b>     |
| Complete line of molded barrier type of terminal blocks. Soldering lugs, jumpers, marker strips for above. Complete line of electrical wiring devices. Electronic and aircraft switches made to JAN-S-23 specs.  |                 |
| <b>Kupfrian Mfg. Co., Binghamton, N.Y.</b>   | <b>372</b>      |
| Flexible shaft couplings, flexible shaft assemblies, wire shielding, and push-pull controls.   |                 |
| <b>Laboratory for Electronics, Inc., Boston 15, Mass.</b>  | <b>461</b>      |
| Model 401, wide-band, precision oscilloscope, model 101 pound magnetometer, and mercury delay lines.   |                 |
| <b>Lambda Electronics Corp., Corona 74, N.Y.</b>   | <b>345</b>      |
| Laboratory power supplies.   |                 |
| <b>La Pointe-Plascomold Corp., Windsor Locks, Conn.</b>  | <b>464</b>      |
| Television antennas, boosters, lightning arrestors, and accessories.   |                 |
| <b>Lavoy Laboratories, Inc., Morganville, N.J.</b>   | <b>87, 88</b>   |
| Oscilloscopes, signal generators, frequency meters, mechanical assemblies, transformers for military applications.   |                 |
| <b>Lewis and Kaufman Inc., Los Gatos, Calif.</b>   | <b>502</b>      |
| Tubes.   |                 |
| <b>Libbey-Owens-Ford Glass Co. (Plaskon Div.) Toledo 8, Ohio</b>   | <b>140</b>      |
| Plaskon Alkyd Mobile Unit is a trailer with a self-contained exhibit consisting of—a lounge area with a display on successful uses of alkyd materials in the radio and television industry—a high voltage test that demonstrates the alkyd plastics' superior electrical properties—and two fully automatic, ultra high-speed, plastic molding machines for high-rate production. See the demonstration which is located outdoors at the right rear first floor of Grand Central Palace. Watch for the sign. |                 |
| <b>Linde Air Products Co., New York 17, N.Y.</b>   | <b>51-53</b>    |
| Xenon, krypton, argon, neon, helium, and rare gas mixtures. Synthetic sapphire boules, rods, balls, centerless ground rounds, and synthetic rutile.  |                 |
| <b>Littelfuse, Inc., Chicago 40, Ill.</b>  | <b>130</b>      |
| Fuses and fuse mountings.  |                 |
| <b>Lord Manufacturing Co., Erie, Pa.</b>   | <b>N-5</b>      |
| Shock Mountings for mobile electronic equipment; temp-proof mountings and equipment bases for equipment protection at high and low temperatures; precision type friction drive wheels; flexible couplings from 1/50 to 100 hp; specialized flexible mountings for protection of sensitive equipment, component parts, meters, instruments, etc.  |                 |
| <b>MB Mfg. Co., Inc., New Haven 11, Conn.</b>  | <b>S-16</b>     |
| Model C25, 2500 pound vibration exciter. Model C1, 50 pound vibration exciter. Model SD, 10 pound vibration exciter. Model R2 ratio box, Models 124, 125, 126 and 127 vibration pickups, Model M1 Meter.   |                 |
| <b>Machlett Laboratories, Inc., Springdale, Conn.</b>  | <b>96, 97</b>   |
| Electron tubes for broadcasting communications and industrial applications specifically to high power triodes which have both broadcasting and industrial applications. With these tubes it is possible to obtain a single tube power output up to 150 kw. Also ruggedized tubes for rf heating applications up to 150 kw. Cottrell smoke precipitator model will form center of exhibit. Will actually operate using Machlett 102 high vacuum rectifier tubes.  |                 |
| <b>MacIen Corp., Washington 17, D.C.</b>   | <b>496, 497</b> |
| Airborne navigational and communications equipment, ground station communications equipment, unclassified electronics equipment being produced on prime and subcontracts, heavy duty rectifier equipment for battery charging, dc power and jet airplane starting. Schuttig and Company Type S227A Glide Slope receiver for instrument landing.  |                 |

(Continued on page 128A)

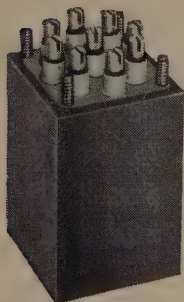
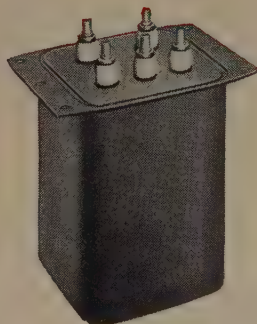
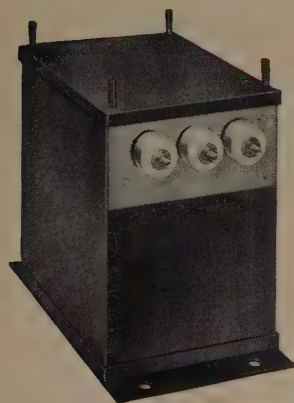
# Precision Built

*for the  
Finest Equipment*



# FERRANTI

## Transformers



Our long experience in building all types of transformers, including hermetically sealed units, qualifies us as a dependable supply source for transformers used in military applications. We offer sound engineering and faultless craftsmanship . . . custom design with the economy and speed of modern mass production methods.

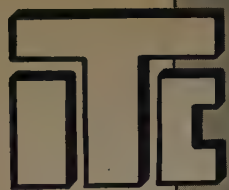
Hermetically Sealed Types for MIL-T-27 applications . . . Special Cores . . . High Temperature Insulation . . . as well as all normal types for every purpose.

**FERRANTI ELECTRIC, INC.**

30 Rockefeller Plaza, New York 20, New York

*There is No Finer Name in Transformers than*

# FERRANTI

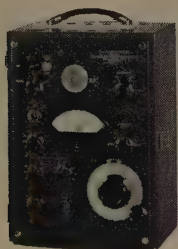


# INSTRUMENTS THAT BELONG IN *Your* LABORATORY



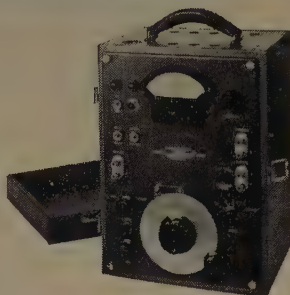
**Type 310-A Z-Angle Meter —**  
30 to 20,000 c.p.s.

Measures impedance directly in polar coordinates as an impedance magnitude in ohms and phase angle in degrees  $Z/\pm \Theta$ . Measures, with equal ease, pure resistance, inductance, capacitance or complex impedances comprised of most any RLC combinations. Range: Impedance (Z), 0.5 to 100,000 ohms; Phase Angle ( $\Theta$ ),  $+90^\circ$  (Xl) through  $0^\circ$  (R) to  $-90^\circ$  (Xc). Accuracy: Within  $\pm 1\%$  for impedance and  $\pm 2^\circ$  for phase angle. Price: \$470.00.



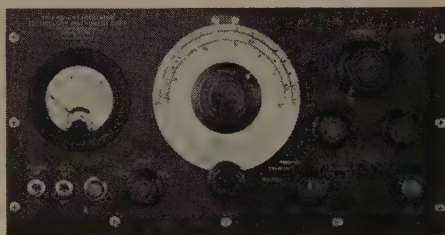
**Type 311-A R-F Z-Angle Meter**  
for radio frequencies — 100 kc to 2 mc.

Simplifies laboratory and field impedance and phase angle measurements. Ideal for checking impedance of coils, transformers, coupling networks, lines, filters, antennas, etc. Direct-reading Impedance Range: 10 to 5,000 ohms up to 200 kc, and 10 to 1,000 ohms at 1 mc. Phase Angle:  $+90^\circ$  (Xl) through  $0^\circ$  (R) to  $-90^\circ$  (Xc). Accuracy: Impedance to within  $\pm 3\%$ , and phase angle  $\pm 4^\circ$ . Price: \$385.00.



**Type 410-A R-F Oscillator —**  
100 kc to 10 mc. (Special models  
46.5 kc to 4.65 mc available.)

Power oscillator for use as bridge driver and general laboratory measurements. Features: High stability, high output (approximate 30 volts), 50-60  $\Omega$  output impedance, expanded frequency scale, direct reading output voltmeter, compact design. Price: \$385.00.



**Type 320-A Phase Meter —**  
frequency range 20 cycles to 100 kc.

The first commercially available all-electronic instrument that directly measures the phase angle between two voltages in a simple operation. Ideally suited to applications in such fields as audio facilities, ultrasonics, servomechanisms, geophysics, vibrations, acoustics and many others.

Phase angle readings made directly without balancing . . . stable at frequencies as low as 2 to 3 cycles. Voltage range: 1 to 170 peak volts. Terminals for recorder . . . choice of relay-rack or cabinet mounting.



**Type 500-A Wide Band Decade Amplifier**

Designed for use with the phase meter at voltage levels below one volt and as a general purpose laboratory amplifier—features high gain negligible phase shift and wide band width. Unique circuitry—which employs three cathode followers—offers wider frequency range, higher input impedance and lower output impedance than other types. Panel switch selects proper feedback compensation when either optimum amplification or phase shift operation is desired.

Outstanding specifications: Amplification—10; 100; 1000 selected by rotary switch . . . Accuracy— $\pm 2\%$  nominal . . . Frequency response— $\pm 0.5\text{db}$  from 5 cycles to 2mc on gain of 10;  $\pm 0.5\text{db}$  on 5 cycles to 1.5mc on gain of 100;  $\pm 0.8\text{db}$  from 5 cycles to 1mc on gain of 1000 . . . Phase shift— $0 \pm 2^\circ$  from 20 cycles through 100kc . . . Gain stability—constant with line voltages (105-125v).



Prices: Single Type 500-A in cabinet, \$205.00 (Rack mount, \$200.00); Dual Type 500-AR in cabinet, \$425.00.

Technical catalog—yours for the asking. Contains detailed information on all TIC Instruments, Potentiometers and other equipment. Get your copy without obligation—write today.



## TECHNOLOGY INSTRUMENT CORP.

535 Main Street, Acton, Massachusetts

Engineering Representatives

Cleveland, Ohio Prospect 1-6171

Chicago, Ill.—Uptown 8-1141 New York, N.Y.—Murray Hill 8-5858 Rochester, N.Y.—Munroe 3143  
Cambridge, Mass.—Eliot 4-1751 Canaan, Conn.—Canaan 649 Hollywood, Cal.—Hollywood 9-6305  
Ann Arbor, Ontario—Ann Prior 400 Dayton, Ohio—Michigan-8721 Dallas, Texas—Dixon 9918

Booth No. 101, Radio Engineering Show

## What to see at the Radio Engineering Show

(Continued from page 126A)

Firm	Booth
Magnecord, Inc., Chicago 1, Ill. Tape recorders.	308, 310
Magnetic Amplifiers, Inc., Long Island City 1, N.Y. Standard push-pull magnetic amplifiers. Magnetic servo amplifiers. Tubeless synchro servo systems. Tubeless high power servo systems. Tubeless voltage regulator.	460
Magnetics, Inc., Butler, Pa. High permeability tape wound cores, and magnetic amplifiers. Magnetic computer cores of ultra-thin (less than one mil) materials.	478
D. E. Makepeace, Attleboro, Mass. Electronic parts and assembly. Precision drawn wave guide tubing. Collector and brush assemblies. Contact parts and assemblies. Special shaped tubing and wire. Precious metals for industry. Silver and gold solder.	435
P. R. Mallory & Co., Inc., Indianapolis 6, Ind. Capacitors, high density metals, rectifiers, tuners, switches, vibrators, mercury batteries, and contacts, TV converter for uhi.	37, 38
Marconi Instruments Ltd., New York 4, N.Y. FM and AM signal generators, Q meters, admittance bridges, X band test sets, direct-reading high frequency wavemeters, kickstarters, vacuum tube voltmeters, and FM deviation meters.	137
Marion Electrical Inst. Co., Manchester, N.H. Ruggedized, hermetically sealed, electrical indicating instruments, standard bakelite-cased instruments, null indicators, elapsed time indicators, and PM1 induction heating unit.	201
McGraw-Hill Publishing Co., New York 18, N.Y. Publications and books. <i>Electronics</i> —technical radio magazine— <i>Nucleonics</i> —technical magazine for nuclear field.	200
McIntosh Eng. Labs., Inc., Binghamton, N.Y. Audio amplifiers.	308, 310
Measurements Corp., Boonton, N.J. Standard signal, pulse, square wave, and television signal generators. UHF radio noise and field strength, meters, megohm meters, peak voltmeters, rf attenuators, crystal calibrators, intermodulation meters, megacycle meters, inductance bridges, capacitance bridges, vacuum tube voltmeters, special test instruments.	226, 227
Mepco, Inc., Morristown, N.J. Precision wire wound, and meter multiplier resistors.	N-8
Metalcraft, Inc., Richmond Hill 18, L.I., N.Y. Precision sheet metal products; cabinets, chassis, and boxes.	501
Metal Textile Corp., Roselle, N.J. Metex electronic weather stripping. Resilient metallic shielding gaskets and strips for suppressing radio-noise and TVI. Special electronic application of knitted wire shapes, including radar reflectors, tube grids, washers, etc.	466
Micro Switch, Div. of Minneapolis-Honeywell Reg. Co., Freeport, Ill. AN and JAN type toggle switches; subminiature push button switches, panel sealed, multi-pole. Mercury switches. Subminiature toggle switches. Precision snap acting switches, AN and JAN types. Aircraft switches for various functions.	N-18
Microwave Development Labs., Inc., Waltham 54, Mass. Waveguide Components.	476
Mil Instrument Corp., Long Island City 1, N.Y. Panel meters as per JAN-1-6 and MIL 6A.	493
James Millen Mfg. Co., Inc., Malden 48, Mass. Delay lines, magnetic metal shields, grid dip meters (with a range to 225 kc). Laboratory equipment, electronic components.	42

(Continued on page 130A)



# INSTANT ACTION!



SEE US!  
Booth No. 252  
I.R.E. SHOW

**KESTER  
SOLDER**

## NEW KESTER "44" RESIN CORE SOLDER

ESPECIALLY FOR TV... RADIO WORK...  
EVERYTHING ELECTRONIC

In speed of action for fast soldering, this product far surpasses anything in the Industry today. Unbelievably more active and mobile... absolutely non-corrosive and non-conductive.

For an actual demonstration in your plant, contact Kester's Technical Department.

Conforms with following specifications:  
Federal QQ-S-571b  
Army-Navy-Air Force Mil-S-6872 (AN-S-62)  
U. S. Air Force No. 41065-B-Method 31

**KESTER SOLDER COMPANY**

4219 Wrightwood Ave., Chicago 39  
Newark, N.J.      Brantford, Canada

# NEW OSCILLATORS

.009 to 520,000 cps.

MODEL  
400-A



MODEL  
420-A

.35 to 52,000 cps.

.009 to 1,100 cps.  
True sine wave oscillator circuit.  
No tuning or switching transients.  
Price \$350.00

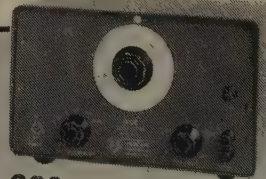
Audio and Sub-Audio ranges.  
Fast AVC action.

Price \$290.00

## EACH MODEL FEATURES

- Both sine and square waves, simultaneously.
- Good amplitude constancy,  $\pm 1$  db over the entire frequency range.
- Low distortion, less than 1%.
- Accurate calibration, better than  $\pm 2\%$ .
- Single scale logarithmic dial with vernier tuning control.
- Sine Wave Output, 30 volts peak to peak.
- Low Hum and d-c component, less than 0.1% of output at any level.
- Calibrated logarithmic output level control.
- Input power, 45 watts.
- Small size, overall 12" x 7" x 8".

MODEL  
430-A



4.5 to 520,000 cps.

- Good Amplitude constancy,  $\pm 1$  db over the entire frequency range.
- Low distortion, less than 1% at any frequency.
- Accurate calibration,  $\pm 1.5\%$ .
- Five decade Bands.
- Single scale logarithmic dial.
- Calibrated logarithmic output level control.
- Fast AVC action.
- Small size, overall 12" x 7" x 8".
- Price \$145.00.



MODEL  
410-A

.018 to 22,000 cps.

- Both sine and square waves, simultaneously.
- Excellent amplitude constancy,  $\pm 0.25$  db over the entire frequency range.
- Extremely low distortion, less than 0.25% at any frequency.
- Fast recovery from transients.
- Accurate calibration  $\pm 1.5\%$ .
- Single scale logarithmic dial.
- Calibrated output attenuator switch.
- Constant impedance "T" pad output control.
- Vernier tuning control.
- Price \$950.00

All KROHN-HITE Instruments are fully guaranteed for one year against defective materials and workmanship.

**KROHN-HITE INSTRUMENT**  
*Company*



580 MASSACHUSETTS AVENUE, CAMBRIDGE 39, MASS., U.S.A.

## What to see at the Radio Engineering Show

(Continued from page 128A)

Firm	Booth
J. W. Miller Co., Los Angeles 3, Calif.	454
Radio coils and allied products: rf chokes, inductors, filters, network, rf and IF transformers, delay lines, etc.	
Millivac Instrument Corp., Schenectady 6, N.Y.	457
Memoscope (self recording oscilloscope), "Lofyld" power transformer, ac-microvoltmeter, dc-microvoltmeter, dc-micro-microammeter.	
Mucon Corp., Newark 5, N.J.	480
Miniature ceramic capacitors, uhf ceramic capacitors, and printed circuit applications.	
Multi-Metal Wire Cloth Co., Inc., New York 59, N.Y.	487, 488
Cathode-ray tube shields, cabinets, chassis, dust covers, panels, racks and shields.	
Muter Co., Chicago 5, Ill.	312
Ceramic capacitors, wire wound resistors, rf and IF coils, precision potentiometers, switches.	
Mycalex Corp. of America, New York 20, N.Y.	82, 83
"Mycalex (glass-bonded mica) insulating materials: "Mycalex 400" series, sheets, rods and fabricated parts. "Mycalex 410" and "Mycalex 410X" series, injection molded with or without inserts to specifications. "Mycalex K" series, capacitors, dielectrics in sheets, rods and molded parts. "Mycalex" components and end-products such as: "Mycalex 410" and "Mycalex 410X" Miniature and Subminiature and uhf tube sockets, terminal capacitors, miniature tie-in terminals; "Mycalex 410" telemetering switches and telemetering commutators.	
N. R. K. Mfg. & Engineering Co., Chicago 45, Ill.	N-19
Radar components, and waveguide assemblies.	
National Carbon Div., Union Carbide & Carbon Corp., New York 17, N.Y.	51-53
"Eveready" radio batteries, hearing aid batteries, batteries for radiation detectors, photo-flash, and miscellaneous electronic equipment.	
National Co., Inc., Malden 48, Mass.	S-11
Communications equipments and electronic components.	
National Research Corp., Vacuum Engineering Div., Cambridge 42, Mass.	133
Vacuum gauges to read from atmosphere down to $10^{-10}$ mm. of mercury. Booster and diffusion pumps for electronic applications. Crystal coating equipment. High vacuum valves. Leak detecting equipment for high speed rotary exhaust machines. Gas-free high purity metals and alloys.	
New Hermes Engraving Machine Corp., New York 3, N.Y.	N-21, N-22
Portable and bench type engraving machine for both metal and plastics.	
The J. M. Ney Co., Hartford 1, Conn.	220
Precious metal alloys; as they are used in instruments.	
Northern Radio Co., Inc., New York 11, N.Y.	307
Communications receiving and transmitting equipment.	
Nuclear Instrument & Chemical Corp., Chicago 10, Ill.	393B
Portable alpha-beta-gamma survey instruments. Civil defense high level radiation detector, G-M probes, scalars, and monitors.	
Nucleonics, New York 18, N.Y.	200
See: McGraw-Hill Pub. Co.	
Oak Mfg. Co., Chicago 10, Ill.	447
Rotary, push button, and slider switches, television tuners, vibrators, and power supplies, variable capacitors, Ledex Rotary solenoids, and other special devices requiring a combination of electrical-mechanical know-how.	
Oak Ridge Products, Long Island City 1, N.Y.	493
Portable precision test equipment.	
Ohmite Mfg. Co., Chicago 44, Ill.	282
Resistors, rheostats, rotary tap switches, rf chokes, and dummy antennas.	
Olympic Metal Products Co., Inc., Phillipsburg, N.J.	481
Metal enclosures—drawn covers with folded case bodies. Drawn seamless metal	

(Continued on page 131A)

# What to see at the Radio Engineering Show

(Continued from page 130A)

## Firm Booth

cases. Transformer shields and end bells. Transformer channel frames and mounting brackets. Special hyper-sil core mounting brackets, and Mil-T-27 transformer cases.

**Optical Film Engineering Co.** Philadelphia 33, Pa. 453

High vacuum evaporators for making mirrors, resistors, crystal coatings, etc. Oil diffusion pumps. Tube pumping units. Evaporated conducting films.

**Panelyte Division, St. Regis Sales Corp.,** New York 17, N.Y. 456

Laminated insulation products—sheets, rods, tubes, fabricated parts, injection molded parts, reinforced plastics. Decorative Panelyte. Silicone resin laminates, nylon base laminates, copperclad laminates for printed circuits, phenolic and melamine glass base laminates.

**Panoramic Radio Products, Inc.,** Mt. Vernon, N.Y. N-6

Model AP-1 Panoramic sonic analyzer. Model LP-1 Panoramic sonic analyzer. Model SB-7 Panoramic ultrasonic analyzer. Model G-2 Panoramic sonic response indicator. Models SA-3, SA-8 Panadaptors. Models SB-3, SB-8 Panalyzers.

**Par-Metal Products Corp.,** Long Island City, N.Y. N-10

Relay racks, cabinets, chassis, panels and metal parts.

**Phalo Plastics Corp.,** Worcester 8, Mass. 443

Plastic wire and cable, cable assemblies wiring harness, cord sets.

**Philco Corp.,** Philadelphia 32, Pa. 43, 44

Microwave radio relay communications equipment. Time division multiplex equipment. Electronics training materials for the armed forces and industry. Technical publications.

**Photo Chemical Products, Inc.,** Long Island City 5, N.Y. 486

Aircraft dials, panels for electronic equipment, chassis for electronic equipment, TV and radio dials, terminal boards and schematics.

**Photocircuits Corp.,** Glen Cove, L.I., N.Y. 463

"Printed Circuits"—etched foil circuits on foil clad laminates and allied electronic assemblies. Flush disk type wiping contacts, commutators and switches.

**Pioneer Elec. & Research Corp.,** Forest Park, Ill. 490

Wire line switching system, program receiving system, miniature motors. The electrowriter a remote-positioning device which produces handwriting or sketches over a long distance line.

**Plastoid Corp.,** Long Island City 1, N.Y. 451

Various types of electric wire and cable constructions.

**Polarad Electronics Corp.,** Brooklyn 11, N.Y. S-7

LSA spectrum analyzer (10 to 22,000 mc) microwave signal source, klystron power supply, portable picture monitor, TV oscilloscope, Radio cue system, master monitor, monoscope signal source, synchronization, generator, distribution amplifier.

**The Polymer Corp. of Pa.,** Reading, Pa. 465

Nylon rod, strip and tubing, fabricated parts, teflon: (complete line) Rod, strip, tubing fabricated parts, molded parts, coated parts.

**Polytechnic Research & Dev. Co., Inc.,** Brooklyn 1, N.Y. 268, 269

VHF-UHF Sweep frequency generator and noise source, Microwave test equipment.

**Potter & Brumfield,** Princeton, Ind. 240

Relays—sensitive types, Relays—hermetically sealed types.

**Potter Instrument Co.,** Great Neck, L.I., N.Y. 109

Model 801 Megacycle frequency-time counter, Model 450 1.6 megacycle counter-chronograph, Model 516 Megacycle Preset interval generator, Model 131 Predetermined electronic counter.

**Precise Development Corp.,** Oceanside, L.I., N.Y. 455

Vacuum tube voltmeters. RF probes, high voltage probes, signal generators, etc., in wired and kit form.

(Continued on page 132A)

## NEW ELECTRONIC FILTERS

### BAND PASS • REJECTION • SERVO

MODEL  
330-A  
BAND-PASS

Maximum attenuation  
greater than 80 db. Unity  
pass band gain.



0.02 to 2,000 cps.  
24 db/octave each side

MODEL  
350-A  
REJECTION

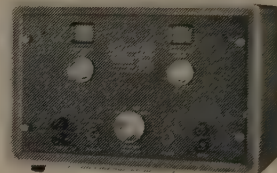
Band rejection or sharp  
null filtering. Unity gain  
outside rejection region.

#### EACH MODEL FEATURES

- High and low cut-off frequencies independently tuned over the entire frequency range
- Adjustable center frequency
- Adjustable band width
- 24 db/octave attenuation rates with peaking to reduce corner frequency attenuation
- Single scale logarithmic dials
- Five decade bands
- Internal noise less than 100 microvolts
- Maximum input signal 10 volts
- Output impedance 500 ohms or 5,000 ohms
- Input and output buffer stages
- Electronic regulated supplies
- Excellent gain and calibration constancy
- Price \$450.

MODEL  
340-A  
SERVO-DESIGN

0.01 to 100 cps.

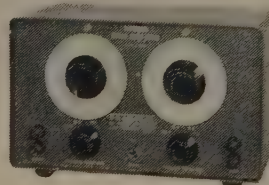


For use in the d-c path of a servo loop to obtain either proportional-plus-integral or proportional-plus-derivative correction for experimental determination of optimum filter characteristics.

- Direct reading in frequency and attenuation ratio
- Single scale logarithmic dials
- Four decade bands
- Input and output buffer stages
- Electronic regulated supplies
- Filament drift cancellation
- Good gain and calibration constancy
- Price \$350.

MODEL  
310-A  
BAND-PASS

Maximum attenuation  
greater than 60 db. Unity  
pass band gain.



20 to 200,000 cps.  
24 db/octave each side

MODEL  
360-A  
REJECTION

Band rejection or sharp  
null filtering. Unity gain  
outside rejection region.

#### EACH MODEL FEATURES

- High and low cut-off frequencies independently tuned over entire frequency range
- Adjustable center frequency
- Adjustable band width
- 24 db/octave attenuation rates with peaking to reduce corner frequency attenuation
- Single scale logarithmic dials
- Four decade bands
- Internal noise less than 5 millivolts
- Maximum input signal 5 volts
- Output impedance 500 ohms
- Input and output buffers
- Good gain and calibration constancy
- Small size
- Price \$275.

All KROHN-HITE Instruments are fully guaranteed  
for one year against defective materials and workmanship.

# KROHN-HITE INSTRUMENT Company



DEPT. P 580 MASSACHUSETTS AVE. CAMBRIDGE 39, MASS. U.S.A.

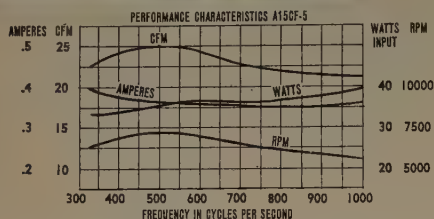
## What to see at the Radio Engineering Show

(Continued from page 131A)

Firm	Booth
Precision Apparatus Co., Inc., Elmhurst, L.I., N.Y.	205
Electronic Test and measuring instruments. AM and sweep signal generators, cathode-ray oscillographs, vacuum tube voltmeters, circuit analyzers, voltohmmillimeters, tube testers, high potential test probes.	
Presto Recording Corp., Hackensack, N.J.	315
High fidelity sound recording equipment and disks with emphasis on a new type of long playing tape recorder for monitoring communications. (Continuous unattended operation for 16 hours.)	
Price Electric Corp., Frederick 1, Md.	418
Various types of relays.	
Product Development Co., Inc., Kearney, N.J.	365
Microwave parabolic antenna, broadband coaxial transmission lines and associated system components. Expanded all aluminum mesh parabolic reflectors.	
Production Tool & Fixture Co., Oyster Bay, L.I., N.Y.	351
Wiring fixtures (6 types), pin straighteners, dummy plugs, masking plugs, and connectors.	
Pyramid Electric Co., N. Bergen, N.J.	208
Dry electrolytic, standard paper, metallized paper, and "glassal" paper capacitors. rf interference filters.	
REF Manufacturing Corp., Mineola, L.I., N.Y.	373
Fabricated sheet metal parts; assembled cabinets; riveted and welded structures.	
Racon Electric Co., Inc., New York 3, N.Y.	313
Re-entrant horns, driver units, marine loudspeakers, explosion-proof units, tweeters, and microphone stands.	
Radio Communication (FM-TV), Great Barrington, Mass.	325
TV and audio broadcasting, and communications systems operating in the mobile, point-to-point, and relay services.	
Radio Corp. of America, Camden, and Harrison, N.J.	4-9
Electron tubes for radio, television, communications, and industry electronic components, dry batteries, test and measuring equipment.	
Radio Electronics, New York 7, N.Y.	S-2
Radio-Electronics magazine. Gernsback Library Books.	
Radio Magazines, Inc., New York 17, N.Y.	94A
Audio Engineering (Magazine). Audio Anthology (compiled from Audio Engineering). Ultrasonics Fundamentals.	
Radio Materials Corp., Chicago 18, Ill.	N-12
Ceramic capacitors.	
Radio Receptor Co., Inc., New York 11, N.Y.	N-16
Selenium, and germanium rectifiers.	
Radio & Television News, New York 7, N.Y.	222
(Magazines) Radio & Television News.	
Radioactive Products, Inc., Detroit 26, Mich.	398
Instruments for the measurement of radioactivity including scalars, gamma survey meters, alpha survey meters, and neutron survey meters.	
Rahm Instruments, Inc., New York 7, N.Y.	271
Direct recording oscillographs. Signatron transducer and telemetering systems.	
Rangertone, Inc., Newark 4, N.J.	320A
Magnetic tape recorders, primarily for motion picture sound; Synchronizers for tape recorders, and variable power drives, tape-to-film editor for motion picture sound. Very light weight battery operated synchronous sound tape recorder, camera-to-tape Syncrotac for Lip-Sync TV news film recordings.	
The Rauland Corp., Chicago 41, Ill.	344
Cathode-ray tubes for television purposes.	
Rawson Electrical Instrument Co., Cambridge 42, Mass.	245
Precision laboratory portable meters, electrostatic voltmeters, sine cosine potentiometers, Lush-Rawson rotating coil gaussmeter for magnetic field measurements.	

(Continued on page 134A)

## THE LATEST IN VARIABLE FREQUENCY BLOWERS WITH FLAT SPEED TORQUE CURVES



**TYPE A15CF-5:** Centrifugal blower, variable frequency capacitor induction motor driving LR #2 blower, single phase, self cooled, weight 22 oz., 22 CM, NEMA, (free air) average delivery, 6250 RPM average speed, 115 volts, 320-1000 cycles can be supplied with CW and CCW. This unit is designed with silicone insulation and impregnation and is used to cool a high power vacuum tube which requires a maximum of air speed over the entire frequency range and in particular over an altitude range of sea level to 50,000 feet.

Example above is indicative of our "know-how" design ability. May we aid in the solution of your problem?

Ruggedly constructed durable motors (precisely designed for 400 cycles—60 cycles—variable frequency) operating dependably in equipment requiring specialized performance, are being produced with superior accuracy through the advanced ideas of our designing engineers.

Experimental production, made possible through flexible engineering experience plus experienced production, has resulted in production designs that include motors for fan and blower duty as well as power and drive motors; these will be made exclusively for the electronic industries supplying equipment for military applications.

Ours is an experienced organization with engineering model shop and electrical laboratory for prototypes—this means you gain personnel with "know how" to solve your special motor and A.C. power problems.

**SEE US AT THE SHOW • BOOTH 406**

**AIR MARINE MOTORS INC.**  
2183 JACKSON AVENUE, SEAFORD, L. I., N. Y.  
WAntagh 2-7309

## ATTENUATORS by TECH LABS



"Midget" model is especially designed for crowded apparatus or portable equipment.



STANDARD  
TYPE  
700

- Solid silver contacts and stainless silver alloy wiper arms.
- Rotor hub pinned to shaft prevents unauthorized tampering and keeps wiper arms in perfect adjustment.
- Can be furnished in any practical impedance and db. loss per step upon request.
- TECH LABS can furnish a unit for every purpose.
- Write for bulletin No. 431.

**TECH**  
LABORATORIES, INC.

Manufacturers of Precision Electrical Resistance Instruments  
PALISADES PARK • BOX 148 • NEW JERSEY

# International

## Selenium Rectifiers

for unsurpassed  
performance

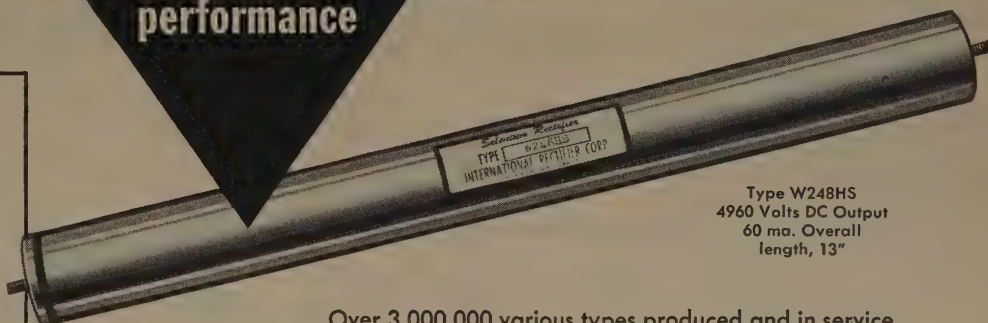
### TYPE W-HS-SERIES 60 Milliamperes DC

In 1 1/4" Phenolic Tube with stud mounting at each end. Circuit-Half-Wave. Overall length varies to 14", depending on DC Output Voltage rating. For many applications for heavier duty and inverse peak suppressor circuits.

#### PARTIAL LISTING W-HS SERIES

DC Output Voltage	Rectifier Part No.
20	W1HS
60	W3HS
100	W5HS
400	W20HS
800	W40HS
1500	W75HS
2500	W125HS
3500	W175HS
4500	W225HS
6000	W300HS

Over 500 other types

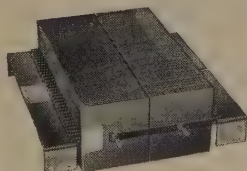


Type W248HS  
4960 Volts DC Output  
60 ma. Overall  
length, 13"

Over 3,000,000 various types produced and in service during the past 4 years. Designed and built to meet Government Specifications. Manufactured for temperatures up to 100° C ambient — 100% humidity. A recent month's production included Rectifiers to supply 40 microamperes, 1 volt and Rectifiers with a capacity of 140,000 amperes, 14 volts. Owned and managed by Engineers who are specialists in the design and manufacture of Selenium Rectifiers. Submit your problems for analysis and we will be glad to offer our recommendations.



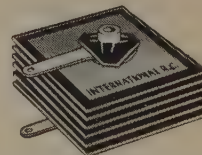
Hermetically sealed  
Cartridge Type Rectifiers



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Ratings to 250 KW



High Voltage Rectifiers  
— Cartridge Type



Miniature Rectifiers —  
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Phone El Segundo 1890

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## BOOTH 130

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# AMPERITE

**THERMOSTATIC METAL TYPE**

## Delay Relays

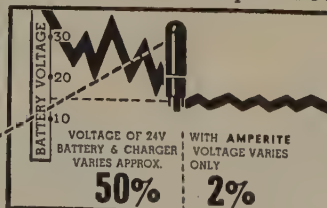


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FROM 1 TO 120 SECONDS**

**FEATURES:** — Compensated for ambient temperature changes from  $-40^{\circ}$  to  $110^{\circ}$  F... Hermetically sealed; not affected by altitude, moisture or other climate changes... Explosion-proof... Octal radio base... Compact, light, rugged, inexpensive...  
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**AMPERITE CO., Inc., 561 Broadway, New York 12, N. Y.**

**In Canada: Atlas Radio Corp., Ltd., 560 King St., W. Toronto**

## What to see at the Radio Engineering Show

(Continued from page 132A)

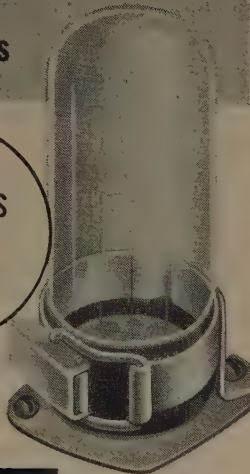
Firm	Booth
Raytheon Mfg. Co., Waltham 54, Mass.	33, 34
Tubes: Power, receiving, transmitting, industrial. Plastic knobs etc.	
Reeves Instrument Corp., New York 28, N.Y.	13
REAC computer equipment (analog), Standard instrumentation breadboard parts, universal precision resolvers, and induction potentiometers.	
The Rex Corp., Cambridge 39, Mass.	339
Rex "Nonstrip" 125°C Microwall insulated wire, Rexolite #1422 ultra-high frequency material.	
John F. Rider Publisher, Inc., New York 13, N.Y.	210
Rider AM-FM-TV-PA service manuals, and electronic textbooks. Rider Tek-File (a monthly technical data service for TV-Radio-PA equipment). A special service of the organization is the preparation of technical literature for government and industry.	
Riester & Thesmacher Co., Cleveland 13, Ohio	438
Various items of metal cabinets, chassis, housing, etc., for the electric and electronics industries.	
Robinson Aviation, Inc., Teterboro, N.J.	S-3
Vibration isolation, and shock control units, devices and systems for airborne installations.	
Edward E. Robinson, Inc., Nutley 10, N.J.	479
Robinson metering pumps for hot and cold cements which are used in the electrical industries for potting transformers, coils, connectors, and capacitor cases. Also, for weather proofing sockets and switches, sealing terminal blocks and moulding capacitor and coil cases.	
Rola Co., Inc., Cleveland 14, Ohio	312
Loudspeakers, deflection yokes and fly-backs, headphones, transformers: Audio types, hermetically sealed types, TV types.	
Raymond Rosen Eng. Products, Inc., Philadelphia 4, Pa.	448
Airborne and receiving telemetering equipment.	
Rotron Mfg. Co., Inc., Woodstock, N.Y.	302
Blowers, fans, heat exchangers, air interlock switches, and tube mounts. Miniature driving motors.	
Rutherford Electronic Co., Culver City, Calif.	335
Model A-2 time delay generator, Model A-4 time delay generator, and Model D-2 calibrator.	
Sanborn Co., Cambridge 39, Mass.	N-13
Several models, both single and multi-channel, of the Sanborn direct-writing recorders, featuring permanent records, made without ink and having true rectangular co-ordinates; also, interchangeable ac and dc preamplifiers, and interchangeable driver amplifiers of dc, strain gage, and other types.	
Sangamo Elec. Co., Capacitor Div., Marion, Ill.	484
Fixed mica, paper, and electrolytic capacitors.	
Carl W. Schutter Mfg. Co., Lindenhurst, L.I., N.Y.	260
Radar and electronic components.	
Scientific Electric, Garfield, N.J.	60
Induction heating equipment.	
Herman Hosmer Scott, Inc., Cambridge 39, Mass.	219
Sound level meters, vibration meters, noise generators, high fidelity and laboratory amplifiers, sound analyzer, Dynaural noise suppressors and amplifiers, and electronic laboratory equipment.	
Servo Corp. of America, New Hyde Park, L.I., N.Y.	348
Servoscope, Servoboard, Servotherm products, servo amplifier, rf signal generator.	
Servomechanisms, Inc., Westbury, L.I., N.Y.	459
Absolute pressure transducers, accelerometers, air speed indicators, amplifiers, servo (dc) apparatus, laboratory automatic control systems; controls, remote; differential pressure gauges, electromagnetic pressure gauges, mechanical development apparatus, modulators, 60 and 440 cps, power supplies, 60 and 400 cps, servo amplifiers, 60 and 400 cps, servo components, servo demonstrator, servomechanisms, servo motors, transducers.	

(Continued on page 136A)

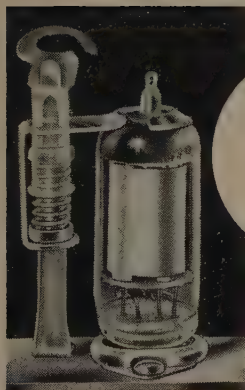
# BIRTCHE TUBE CLAMPS

Hold Tubes in Sockets  
under all Vibration,  
Impact and  
Climatic  
Conditions

83  
VARIATIONS  
FOR  
STANDARD  
TUBES



NEW  
CLAMP  
FOR  
MINIATURE  
TUBES



You can't shake, pull or rotate a tube out of place when it's secured by a Birtcher Tube Clamp. The tube is there to stay. Made of Stainless Steel, the Birtcher Tube Clamp is impervious to wear and weather.

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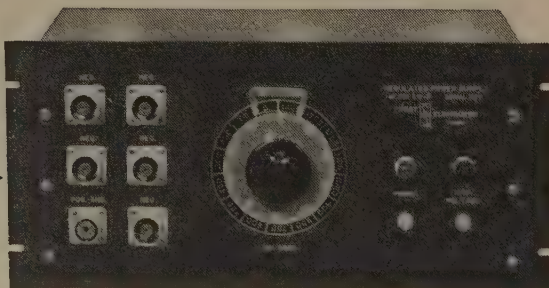
LOW ATTEN. Types	IMPED. Ohms	ATTEN. db100ft. Kw. of 100 Mcs.	LOADG. Kw. of 100 Mcs.	OD."
A.1.	74	1.7	0.11	0.36
A 2	74	1.3	0.24	0.44
A34	73	0.6	1.5	0.88
LOW CAPAC. Types	CAPAC. mmf/ft.	IMPED. Ohms	ATTEN. db100ft. 100 Mcs.	OD."
C 1	7.3	150	2.5	0.36
PC1	10.2	132	3.1	0.36
C11	6.3	173	3.2	0.36
C2	6.3	171	2.15	0.44
C22	5.5	184	2.8	0.44
C3	5.4	197	1.9	0.64
C33	4.8	220	2.4	0.64
C44	4.1	252	2.1	1.03

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150 to 1500 VDC at  
0-5 Milliamperes

This unit is specially designed to supply proper power for making precise quantitative measurements with photomultiplier tubes, klystrons and similar applications.

Voltages are held to close limits even with wide line voltage and load variations.

No meter is required. Accurate voltage readings are made directly from a 15 turn vernier dial which is calibrated to read 1 volt per scale division.

See the Model 810-P and other  
Furst Power Supplies at the  
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### MODEL 810-P SPECIFICATIONS

- OUTPUT VOLTAGE: 150 to 1500 VDC at 0-5 Milliamperes.
- REGULATION: Output voltage varies less than .01% per volt change of line voltage and less than .1 volt with variation of output current from 0 to 5 Milliamperes.
- RIPPLE: Less than 5 Millivolts r.m.s.

Positive output terminal is grounded. 5 negative output connectors (type AN-3102A-18-16-s) are connected in parallel and mounted on front panel.

WRITE FOR DESCRIPTIVE BULLETIN

**FURST ELECTRONICS**

14 S. Jefferson St., Chicago 6, Ill.

## What to see at the Radio Engineering Show

(Continued from page 134A)

- |   |              |
|---|--------------|
| <b>Firm</b>   | <b>Booth</b> |
| The Sessions Clock Co., Forestville, Conn.  | 419, 420     |
| Radio and television switch timers, small snap action Tyniswitches, and Sessco industrial finishes.   |              |
| Shallcross Mfg. Co., Collingdale, Pa.   | 280, 281     |
| Fixed resistance standards; tapped resistance standards; megohm decades; decade voltage dividers; low resistance test sets; attenuators—fixed and variable; Wheatstone bridges; decade boxes; Kelvin-Wheatstone bridges; fault-location bridges; per cent limit bridges; megohm bridges; transmission test sets; delay lines; rotary selector switches. |              |
| Sheldon Electric Co., Irvington, N.J.   | 301          |
| 21" cylindrical, automatic focus, 21" glass-metal, 24", 27" glass-metal (if possible), receiving tubes, wiring devices, starters and rectifier bulbs.   |              |
| Sigma Instruments, Inc., Boston 85, Mass.   | 209          |
| Sensitive, and polarized relays.  |              |
| Simpson Electric Co., Chicago 44, Ill.  | 86           |
| Electrical indicating instruments, Radio, radar and television testing equipment.   |              |
| Mark Simpson Mfg. Co., Inc., Long Island City 3, N.Y.   | 206          |
| High fidelity amplifiers, magnetic tape recorders, high powered amplifiers, and intercommunication systems.   |              |
| Herman H. Smith, Inc., Brooklyn 15, N.Y.  | 323          |
| Wholesaler. Switches—connector, plugs, jacks, hardware, test prods and clips, sockets—fuse lights, and tube shields.  |              |
| Sola Electric Co., Chicago 50, Ill.   | 21           |
| Constant voltage transformers including models for defense equipment components. Automatic voltage booster. "Sensivolt" voltage-sensitive, AC control unit.   |              |
| Sorenson & Co., Inc., Stamford, Conn.   | 236, 237     |
| Voltage regulators (ac); power supplies (regulated dc) Nobatrons; frequency changers; fostering process spectrophotometer power supply.   |              |
| Southwestern Industrial Electronic Co., Houston 19, Tex.  | 394          |
| Model "M-2" Oscillators 1 to 120,000, Model "M-B1" Oscillators 20 to 20,000 portable, Model "L" Oscillators 0.01 to 100, Model "ML-4" oscillators 0.01 to 120,000, Model "D-2" dc amplifier, Model "G-2" strain gauge amplifier, Model "C-2" resistance meters, Model "P-11" portable seismograph, Model "R" voltmeter.                                 |              |
| Speer Resistor Corp., St. Marys, Pa.  | 432          |
| Fixed composition resistors, molded phenolic and iron coil forms, and iron cores.   |              |
| Spencer-Kennedy Labs., Inc., Cambridge 39, Mass.  | S-1          |
| Model 202P Wide band chain amplifier, Model 212TV amplifier, Model 214B chain pulse amplifier, Model 215 television distribution amplifier, Model 300 variable electronic filter, Model 302 variable electronic filter, Model 305 variable electronic filter, and Model 503 fast rise pulse generator.  |              |
| Sperry Gyroscope Co., Div. Sperry Corp., Great Neck, L.I., N.Y.   | 57-59        |
| Klystron tubes for microwave relays, radar local oscillators, beacons, navigational equipment, and bench oscillator purposes. Microline test equipment covering the presently used microwave spectrum.  |              |
| Sprague Electric Co., N. Adams, Mass.   | 27, 28       |
| Capacitors, resistors, Ferroxcube cores, pulse networks, radio interference locators.   |              |
| Square Root Mfg. Corp., Yonkers 2, N.Y.   | 231          |
| Toroidal coils, transformers, coils, and TV antennas.   |              |
| Standard Electric Time Co., Springfield 2, Mass.  | 370          |
| Precision electric timers, and laboratory panel components.   |              |
| Standard Piezo Co., Carlisle, Pa.   | 203          |
| Quartz crystal units for frequency control.   |              |
| Standard Transformer Corp., Chicago 18, Ill.  | 404, 405     |
| Transformers and chokes for all industrial applications, with special emphasis on units meeting MIL-T-27 specifications. Military units will be shown in various stages of manufacture, and in cross-section.   |              |

(Continued on page 138A)

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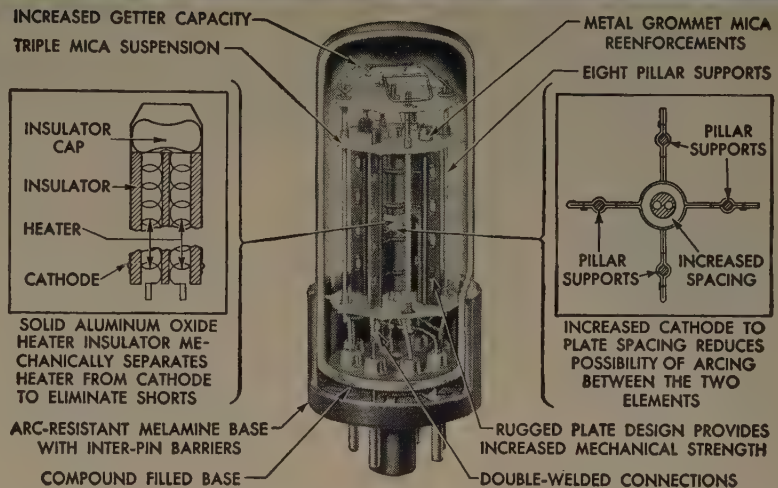
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We are not in the standard vacuum tube business, but we are in the business of developing and manufacturing a reliable line of special purpose electron tubes—tubes that will serve and meet the stiff and varied operational requirements of aviation, ordnance, marine and other fields of modern industry. Typical of these are receiving type tubes such as Beam-Power Amplifiers, R-F Pentodes, Twin Triodes, and the Full-Wave Rectifiers illustrated above and described

below. All of these tubes are exhausted on a special automatic exhausting machine capable of extra high evacuation, and are aged under full operating and vibration conditions for a period of 50 hours. In addition to the tubes described above, Eclipse-Pioneer also manufactures special purpose tubes in the following categories: gas-filled control tubes, Klystron tubes, spark gaps, temperature tubes and voltage regulator tubes.

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Electrical Characteristics of E-P Full-Wave Rectifier Tubes

TUBE TYPE	R.M.A. 5838	R.M.A. 5839	R.M.A. 5852	R.M.A. 5993
Heater Voltage . . . . .	12 volts	26.5 volts	6.3 volts	6.3 volts
Heater Current . . . . .	0.6 amps.	0.285 amps.	1.2 amps.	0.80 amps.
Peak Inverse Voltage . . . .	1375 v. (max.)	1375 v. (max.)	1375 v. (max.)	1250 v. (max.)
Peak Plate Current (per plate)	270 ma. (max.)	270 ma. (max.)	270 ma. (max.)	230 ma. (max.)
D-C Heater-Cathode Potential	450 v. (max.)	450 v. (max.)	450 v. (max.)	400 v. (max.)
Cathode Heating Time. . . .	1 min.	1 min.	1 min.	45 sec.
Total Effective Plate Supply Impedance . . . . .	150 ohms (min.)	150 ohms (min.)	150 ohms (min.)	150 ohms (min.)

Other E-P precision components for servo mechanism and computing equipment:

Synchros • Servo motors and systems • rate generators • gyros • stabilization equipment • turbine power supplies and remote indicating-transmitting systems.

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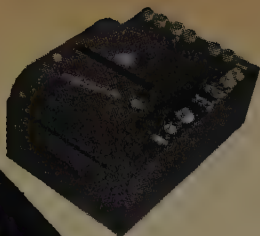
HEILAND LINE

at the Radio

Engineering

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BOOTH 304



708 Recorder



Galvanometer Bank

## MULTI-CHANNEL OSCILLOGRAPH RECORDERS

## GALVANOMETERS

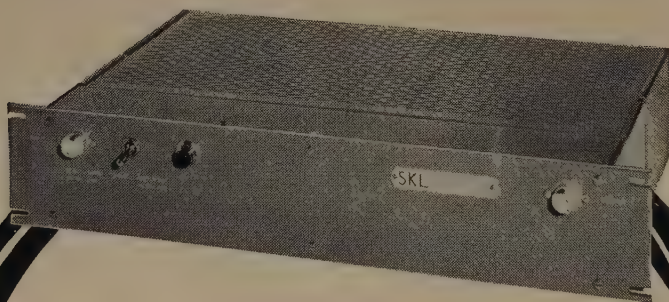
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Model 202P Wide-Band Chain Amplifier with Regulated Power Supply.

Band Width: 100 KC to 200 MC. Gain: 20 db.

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With the Model 202P: vacuum tube voltmeters and oscilloscopes are ten times more sensitive.

With the Model 202P: the output voltage of signal, sweep and pulse generators is ten times greater.

Other Wide-Band Chain Amplifiers available:

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at the I.R.E. Show.

Write for Bulletin 202P-1-E

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186 MASSACHUSETTS AVE., CAMBRIDGE 39, MASS.

## What to see at the Radio Engineering Show

(Continued from page 136A)

- |  |              |
|--|--------------|
| <b>Firm</b>  | <b>Booth</b> |
| Stelma, Inc., Stamford 1, Conn.  | N-4          |
| Receiver, carrier telegraph. Transmitter, carrier telegraph. Regenerative repeater, teletypewriter. A duplex receiving keyer. Bias measuring set, teletypewriter.  |              |
| Stevens Mfg. Co., Inc., Mansfield, Ohio  | 262          |
| Standard and hermetically sealed "Miniature bimetal thermostats" of types M and C—numerous styles of mounting. Also adjustable and non-adjustable "snap-acting" and "positive acting" bimetal thermostats.   |              |
| Stupakoff Ceramic & Mfg. Co., Latrobe, Pa.   | 376          |
| Ceramics including alumina, cordierite, titanates, steatite, porcelain, zircon for all temperatures, voltages, and frequencies. Metallized ceramics and assemblies, kovar metal, glass-to-metal seals, and sub-assemblies, high dielectric materials, and Stupalith.                   |              |
| Sun Radio & Electronics Co., Inc., New York 7, N.Y.  | 319          |
| Display and distribution of the new Sun No. 52 catalog.  |              |
| Superior Electric Co., Bristol, Conn.  | 108, 110     |
| Powerstat variable transformers, stabilizer automatic voltage regulators, varicell dc power supplies, volthox ac power supplies, superior 5-way binding posts, and powerstat light dimming equipment.  |              |
| Suprenant Mfg. Co., Clinton, Mass.   | 401, 402     |
| Hook-up wire, coaxial cables, multiconductor cables, aircraft wire and cable, hearing aid and miniature wires and cables, high temperature insulations, and plastic tubing.  |              |
| Wally Swank, Syracuse, N.Y.  | 221          |
| Advance Electric & Relay Co., Industrial Timer Corp., Curtis Dev. & Mfg. Co., Grayhill, Tru-ohm Div. of Model Engineering & Mfg. Co.   |              |
| Switchcraft, Inc., Chicago 22, Ill.  | 334          |
| Jacks: microphones; phone; telephone Plugs: microphone; phone; telephone Switches: push button, lever action; rotary.  |              |
| Sylvania Electric Products Inc., New York 19, N.Y.   | 104-6, S-8   |
| Subminiature tubes, germanium diodes, radio tube sockets, plastic components, tungsten wire, fluorescent powders and chemicals.  |              |
| Synthane Corp., Oaks, Pa.  | N-1          |
| Laminated plastics products, sheets, rods, tubes. Molded laminated, molded macerated, fabricated parts. Special emphasis on use of laminates in radio, Television and electronics industries.  |              |
| Taylor Tubes, Inc., Chicago 47, Ill.   | 502          |
| High vacuum power tubes, mercury vapor, rectifier tubes.   |              |
| Tech Laboratories, Inc., Palisades Park, N.J.  | 211          |
| Attenuators, switches, (Type 2A, Type 2B, Type 410, Type 409) special motor driven switch, Editall splicing block.   |              |
| Tech-Master Products Co., New York 13, N.Y.  | 267          |
| Custom quality TV chassis, Tech-master 630 TV kits, ac-dc TV kits, booster kits, conversion kits and components.   |              |
| Technical Materiel Corp., Mamaroneck, N.Y.   | 131, 132     |
| Diversity receiving systems, frequency shift converters and exciters, tone channeling equipment, antenna couplers (high and low frequency), regenerative repeater, peak clipping amplifier, airplane crash locator beacon, diversity tuning indicator, and a diversity combining unit. |              |
| Technology Instrument Corp., Acton, Mass.  | 101          |
| Laboratory instruments (320-A phase meter, 310-A Z-angle meter, 311-A rf Z-angle meter, 500-A wide band decade amplifier, 410-A rf oscillator and miscellaneous electronic measuring instruments) and precision potentiometers.  |              |
| Tektronix, Inc., Portland 7, Oregon  | 234, 235     |
| Cathode-ray oscilloscopes, general purpose. Cathode-ray oscilloscopes, millimicrosecond. Square wave generators. Amplifiers, special and general purpose. Electronic apparatus especially adapted to medical uses.   |              |
| Telechrome, Inc., Amityville, L.I., N.Y.   | 266          |
| Color television transmitting equipment for NTSC, RCA, Hazeltine, and CBS color  |              |

(Continued on page 140A)

**MANY NEW  
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Smooth transient response

3-section distributed-type output stage

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.25 μsec signal delay

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### ALL TYPES IN STOCK

- Vacuum Power
- Thyratrons
- Vacuum & Gas. Rect.
- Ignitrons
- Cold-Cathode
- Phototubes
- Oscillograph Tubes
- Camera Tubes
- Monoscopes
- Special Types

**FREE** Interchangeability Directory

Valuable guide to selection of proper RCA tube type replacements. Lists 1600 tube types. Write for FREE RCA Guide No. 37-046.

### Quick, Expert Service on RCA Tubes

ALLIED maintains in stock for quick shipment, the world's largest distributor inventory of RCA special-purpose tubes—of all types. We specialize in supplying the needs of industrial, broadcast, governmental and other users. To save time, effort and money—phone, wire or write to ALLIED. Fill all your needs quickly from the complete, dependable electronic supply source.

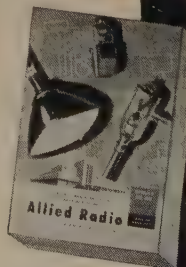
### See Your 1952 ALLIED Catalog

Refer to your ALLIED Catalog for all electronic supplies—parts, tubes, test instruments, tools, audio amplifiers, accessories—available from the world's largest stocks. Write today for your FREE copy of the complete 212-page ALLIED Catalog.

**FREE!** Send for it now

**ALLIED RADIO**

833 W. Jackson Blvd., Dept. 35-B-2 Chicago 7, Ill.



Everything in Electronics from ONE Source

## What to see at the Radio Engineering Show

(Continued from page 138A)

- | Firm  | Booth      |
|---|------------|
| systems. Universal color receiver for receiving any of the above systems. Color bar pattern generator. Inexpensive monochrome picture generator. Microwave noise generator.   |            |
| Telechron Dept., General Electric Co., Ashland, Mass.   | 85         |
| A line of timers and synchronous timing motors. Included are timers for radios, television sets, ranges, refrigerators, washers, and many other products—also telechron timing motors for many applications. The company offers complete application engineering and appearance design service.   |            |
| Tel-Tech see: Caldwell-Clements   | 253        |
| Teletronics Lab., Inc., Westbury, L.I., N.Y.  | 422        |
| Highpower pulse generator. Laboratory pulse generator.  |            |
| Generator and pulse calibrator.   |            |
| Television Equipment Corp., New York 38, N.Y.   | 216        |
| Wide band-high gain general purpose oscilloscope, audio sweep generator with marker generator, "Telmaster" master antenna system, single channel booster (for TV Reception), and a projection oscilloscope.   |            |
| Telex, Inc., St. Paul 1, Minn.  | 452        |
| Dynamic headsets, magnetic headsets, earsets, dynamic pillow speakers, magnetic pillow speakers, and miniature dynamic circuits.  |            |
| Tel-Instrument Co., Inc., East Rutherford, N.J.   | N-14, N-15 |
| Video amplifiers, I.F. distribution amplifiers, rf sweep generator, I.F. sweep generator, 12-channel television picture generator, single channel television picture generator, multi-frequency crystal generator, dot-bar linearity generator, synchronizing generator (B & W, Color, European), monoscope camera (B & W, Color, European), regulated power supply, delay lines, voltage calibrator. |            |
| Tensolite Insulated Wire Co., Inc., Tarrytown, N.Y.   | 426        |
| Plastic insulated wire and cable: Subminiature sizes, extra flexibility, perfect concentricity, high temperature insulation (Teflon).   |            |
| Terminal Radio Corp., New York 7, N.Y.  | 286        |
| Victoreen parts, tubes, resistors, and rate counters for detecting and measuring radioactivity. Also RCA, Mallory and United Transformer.   |            |
| Thomas Electronics, Inc., Passaic, N.J.   | 392        |
| Cathode-Ray Picture Tubes—27" rectangular type.   |            |
| Thompson Products, Inc., Cleveland 3 Ohio   | 305        |
| Coaxial switches for RG-9/U and RG-17/U cable applications (manually and remotely actuated). Radio frequency relays with power switch. Antennas, selective filter amplifiers, polar recorders, wave guide dummy loads, servo components.  |            |
| Thor Ceramics, Inc., Bloomfield, N.J.   | 218        |
| All types of statite: standoff insulators, winding forms, coil forms, pressed parts, machined parts, tube bases, metallized insulators. Also miniature terminal bushings.   |            |
| Tinnerman Products, Inc., Cleveland 1, Ohio   | 391        |
| Speed nuts, speed clips, coil form fasteners, and engineered fasteners.   |            |
| Titeflex, Inc., Newark 5, N.J.  | 483        |
| Flexible waveguides—"Waveflex", Twistable waveguides—"Waveflex", Rigid waveguide components consisting of rotating joints, duplexers, mixers, magic tees, directional couplers, etc. Waveguide hardware, flanges, and special assemblies, etc.  |            |
| Trad Television Corp., Asbury Park, N.Y.  | 495        |
| Frequency shift keyer, URM/25 signal generator, citizen band handi-talkie, variable frequency power supply, and television receivers.   |            |
| Trans-Gel Products, Inc., Queens Village, L.I., N.Y.  | 430        |
| Printed circuits, nameplates, and dials.  |            |
| Trans-Lux Corp., New York 20, N.Y.  | 492        |
| Trans-lux "teleprocess projector" for background scenes in TV studios. Trans-lux "Teleprocess Rear Projection" screens for the same purpose and Teleprocess panoramic slide device provides moving backgrounds in TV studios.   |            |

(Continued on page 142A)

One  
of  
these  
**3**  
materials



may cure your  
insulating headaches

**TEFLON**

**MYKROY**

(glass bonded mica)

**KEL-F**

You are invited to explore the wide possibilities of these 3 materials. They have limitless industrial and electrical applications. From our experience with many extraordinary high voltage, high frequency and high temperature requirements, we are certain one of the 3 will hold the answer you are looking for.

TEFLON, MYKROY and KEL-F are available to you in sheets and rods or molded and machined to your specifications.

Write for descriptive literature on any or all of these materials. We'll be pleased to quote on your own requirements. No obligation.

**ELECTRONIC MECHANICS**  
INC.

101 CLIFTON BOULEVARD,  
CLIFTON, NEW JERSEY

COME SEE US AT BOOTH 336

VISIT OUR BOOTH NO. 334 IRE SHOW

**SWITCHCRAFT**  
INC.

\* **COMPONENT  
PARTS**

Have Earned a Reputation for  
**ADVANCED DESIGN — DEPENDABILITY —  
CONSISTENT QUALITY**

**JACKS—PLUGS—SWITCHES—a complete line  
for industrial or military equipment**

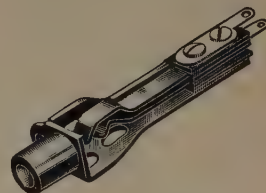
**"LITTEL-JAX"**

Compact, simple design featuring notched Bakelite insulation mechanically interlocking all electrical parts: "V-bend" in tip spring firmly holds mating plug. Available in most common circuits, mounts single  $\frac{3}{8}$ " dia. hole, panels up to  $\frac{5}{32}$ " thick; requires less than 1" behind panel. Available in most common circuits. Military types such as JK-33A (JJ-033), JK-34A (JJ-034) and JJ-089.



**"T-JAX"**

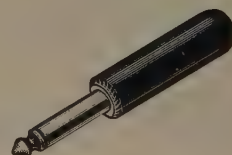
A long-frame type, commonly referred to as a Telephone Switchboard Jack, especially designed for high quality communication equipment. The T-series features fine silver contacts; the ME-series has welded cross-bar Palladium contacts. Available in all standard circuits; the MT type is furnished in all JAN types, for example JJ-024, etc.



**"LITTEL-PLUG"**

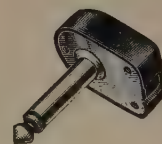
A unique design, features one-piece cable clamp terminal. Lightweight. Fits all standard Jacks. Two and three conductor types; Tenite or Nickel Plated Brass handles.

Another design of approximately same size available in Military Types PJ-054, PJ-055B and PJ-540.



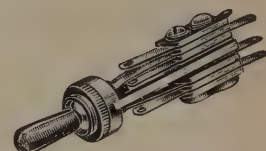
**"FLAT-PLUG"**

Radically new design—removable cover permits use with screw or solder lug terminals. Available in 2- or 3-conductor types; red or black covers. Ideal for business machines, hard of hearing installations, etc., where projecting handle of conventional plug is objectionable.



**"LEV-R SWITCH"**

An unusually small, lever-action switch; available in numerable circuits, to provide the simplest in switching design. Requires only one single round hole for mounting; black plastic knob. Made in 2- and 3-position, locking or non-locking types.



For complete details on these and other Switchcraft products write for catalog S-51.

Available at All Leading Radio Parts Jobbers

**SWITCHCRAFT, INC.** 1328 N. Halsted St., Chicago 22, Illinois

CANADIAN REPRESENTATIVE: Atlas Radio Corporation, Ltd.  
560 King Street, W., Toronto 28, Canada  
Phone: Waverly 4761

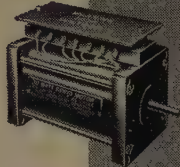
\* The name "Switchcraft" is a registered trade mark and is the property of Switchcraft, Inc.

VISIT OUR BOOTH NO. 334 IRE SHOW



# FORD

10 Watt



Roto Inertia  
0.23 oz.-in.<sup>2</sup>  
Weight  
4.3 lbs.

Write for Descriptive  
Brochure about all  
Ford Control Motors.

## FORD INSTRUMENT COMPANY

Division of The Sperry Corporation

31-10 Thomson Avenue, Long Island City 1, N. Y.

# control motors...

for extremely low inertia and  
high frequency response

### HIGH VOLTAGE MOTORS

60 Cycle, 1½-5-10 watt models

Designed specifically for electronic systems—  
operate directly in the plate circuit of a  
vacuum tube amplifier.

### LOW VOLTAGE MOTORS

60 and 400 Cycle, 2½-5-10 watt models

Recommended for normal two-phase applications.

### advantages

- Linear torque—voltage characteristics
- Linear torque—speed characteristics
- Withstand continuous stalling
- High torque efficiency
- Flexibility of mounting

## What to see at the Radio Engineering Show (Continued from page 140A)

Firm	Booth
Transicoil Corp., New York 13, N.Y.	229
Servo motors, induction generators, precision gear trains, and servo amplifiers.	
Triad Transmitter Mfg. Co. Los Angeles 64, Calif.	507
Hermetically sealed power transformers. Filament transformers, filter reactors.	
The Triplett Electrical Instr. Co., Bluffton, Ohio	257
Electrical indicating measuring instruments, and radio-TV and electrical testing equipment.	
Tru-Ohm Div., Model Eng. & Mfg. See: Wally Swank	221
Truscon Steel Co., Youngstown 1, Ohio	230
Radio Towers for AM-FM-TV and microwave systems.	
George Ulanet Co., Newark, N.J.	445
Thermostats, thermal timers, thermal controls.	
Ungar Electric Tools, Inc., Los Angeles 54, Calif.	421
Soldering irons and pencils.	
Union Carbide & Carbon Corp., New York 17, N.Y.	51-53
See: National Carbon Div. and Linde Air Products Co.	
United States Gasket Co., Camden, N.J.	374
9-pin transformer terminal, sub-miniature teflon tube sockets, 7 and 9-pin miniature tube sockets, crystal sockets, teflon insulators, and teflon covered wire.	
U.S. Dept. of State Radio Supply Depot, "Voice of America," Brooklyn, N.Y.	424
Broadcast antenna.	
U. S. National Bureau of Standards, Washington 25, D.C.	427-429
United Transformer Corp., New York 13, N.Y.	81
Transformers reactors, filter, discriminator coils, high Q coils, magnetic amplifiers to Mil T-27, JAN-T-27-ANE-19 Spec.	
Universal Aviation Corp., New York 17, N.Y.	404
Illuminated lighted panels, dials, lighting assemblies, transformers, motors, relays, etc.	
Universal Winding Co., Providence 1, R.I.	S-4-S-6
Coil winding machinery, including machinery for winding: paper-interleave, layer wound coils; random wind, or bobbin wound coils, and cross-wound or universal wound coils.	
University Loudspeakers, Inc., White Plains, N.Y.	322
Commercial, industrial, military, and high fidelity type loudspeakers. Special attraction: "Listening Post". University senior design engineer will be on hand to give practical answers to all questions pertaining to sound equipment and application problems.	
Vacuum-Electronic Engineering Co., Brooklyn 32, N.Y.	397A
Veeco mass spectrometer leak detector, Bellows-sealed vacuum valves; Bellows-sealed solenoid valves: ¼ swing quick-acting valves.	
Varian Associates, San Carlos, Calif.	55
Six different types of klystrons (X-12, X-13, V-50, V-51, X-21, X-26). Nuclear Resonance equipment.	
Vector Electronic Co., Los Angeles 31, Calif.	331
Vector socket, turrets, plug-in units, and miscellaneous components.	
Vectron, Inc., Waltham 54, Mass.	341
Spectrum analyzers and other electrical and mechanical equipment.	
The Victoreen Instrument Co., Cleveland 3, Ohio	396B
Radiation instruments, sub-miniature tubes, resistors, hi-megohm, Geiger tubes, corona voltage regulators, and low current high voltage power supply.	
Vitramon, Inc., Bridgeport 1, Conn.	446
Capacitors, mica equivalent units—high stability and wide temperature range.	
Waldes Kohinoor, Inc., Long Island City 1, N.Y.	358, 359
Truarc retaining rings. A number of actual customer applications using the various types of rings, will be on display together with samples, literature, etc.	
Waltham Horological Corp., Waltham, Mass.	425
Connectors, terminals, Jack plugs, wave-guides.	
Ward Leonard Electric Co., Mt. Vernon, N.Y.	364
Resistors, relays, rheostats, and controllers.	

(Continued on page 144A)

## Bardwell & McAlister's Line of Television Lights

# TV SPOTS • Designed for Television Studios and Stages

Drawing upon their sixteen years of experience in the production of studio lights used by the motion picture industry, Bardwell & McAlister, Inc. now offers a complete new line of lights especially designed and engineered for TV stage and studio lighting.

### Paint with Light

Painting with light is the ability to control the light source, in order to emphasize the necessary highlights and the all-important shadows. Only through controlled light can the scene or subject be given the desired brilliance, beauty and third dimensional effects.

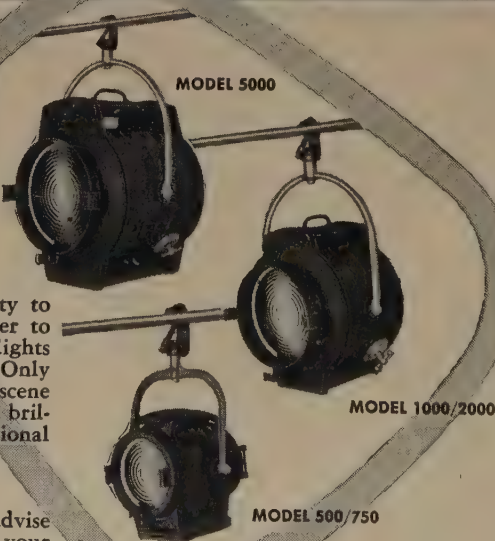
### Our Specialists...

are always ready to assist and advise your engineering staff, so that your studios and stages will be fully equipped to properly "Paint with Light."

Write for complete specifications and prices of these TV SPOTS. Address Dept. 67.

## BARDWELL & McALISTER

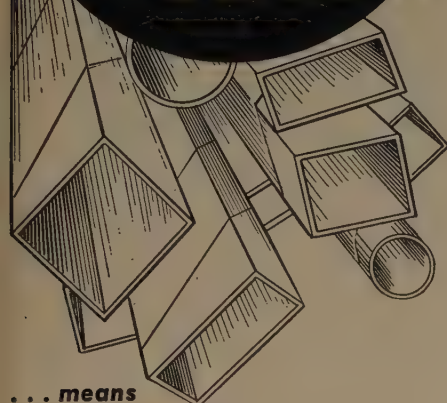
2950 ONTARIO STREET  
BURBANK, CALIFORNIA



**LABORATORY  
CONTROL**  
of



# PRECISION paper TUBES



... means

## FINER COIL FORMS FOR YOU!

- ★ Better Insulation
- ★ More Winding Space
- ★ Better Heat Dissipation
- ★ Lower Moisture Absorption
- ★ Greater Strength
- ★ Lighter Weight

Precision leaves nothing to chance! With all materials under constant Laboratory Control you get coil bases with better heat dissipation, greater resistance to moisture and better insulation. Spiral winding and die-forming under pressure provide 15 to 20% more strength with lighter weight—greater coil winding space.

Available in round, square, oval, rectangular, or any shape, length, ID or OD. Made to your exact specifications of finest dielectric Kraft, Fish Paper, Cellulose Acetate or combinations.

Write today for free sample and New Mandrel List of over 1,000 sizes.

## PRECISION PAPER TUBE CO.

2051 West Charleston St., Chicago 47, Ill.  
Plant No. 2, 79 Chapel St., Hartford, Conn.  
Also Mfgs. of Precision Bobbins

**NOW!**

# Tensolite

MINIATURE and SUB-MINIATURE  
**WIRE & CABLE**  
INSULATED WITH TEFLON®

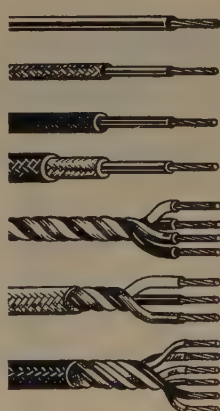
**—for high-temp applications!**

TENSOLON Hook-up Wires and Multiple Conductors are now available in sizes from AWG 30 through 22. They can be supplied with or without wire-braid shields. TENSOLON wire and cable constructions offer outstanding advantage in many respects. Resistance to heat is extremely high and flex-

ibility is excellent, the insulation is tough, offers maximum mechanical protection and is completely moisture-proof. Dielectric strength is very high. TENSOLON is the only wire with TENSULATED DU PONT TEFLON insulation.

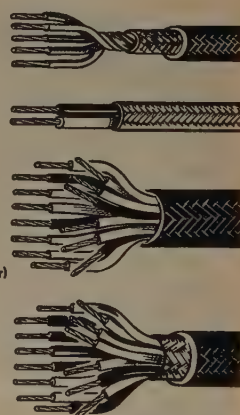
## Tensolite VINYL PRODUCTS

Stranded Sizes from AWG 40 to 20

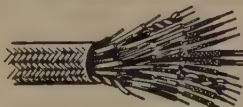


- CLASS A Hook-up Wire
- CLASS B Shielded Lead Wire
- CLASS C Textile-Braid-Covered Lead Wire
- CLASS D Textile-Braid-Covered, Shielded Lead Wire
- CLASS E Twisted (multi-conductor) Cable
- CLASS F Shielded, Twisted (multi-conductor) Cable
- CLASS G Textile-Braid-Covered, Twisted (multi-conductor) Cable

- CLASS H Textile-Braid-Covered, Shielded, Twisted (multi-conductor) Cable
- CLASS I Shielded, Parallel (multi-conductor) Cable
- CLASS J Textile-Braid-Covered, Parallel (multi-conductor) Cable
- CLASS K Textile-Braid-Covered, Shielded, Parallel (multi-conductor) Cable



## Tensolite CUSTOM CONSTRUCTIONS



Constructions to customer specifications

CLASS L—Special wires and cables to customers specifications can be supplied promptly at reasonable cost. Submit your specifications for quote.



Special wire and cable assemblies (units)

CLASS U—Tensolite service includes wire and cable assemblies cut to length, stripped, tinned, pigtailed, etc.—to specifications. Send sketch for quote.

See us at the  
**IRE SHOW**  
BOOTH 426



**WRITE FOR SAMPLES AND CATALOG!**

Tensolite produces a virtually unlimited variety of miniature wire and cable. Service is prompt, efficient and economical. Write for free samples and complete catalog today, on your company letterhead.

**Tensolite INSULATED WIRE COMPANY**  
INCORPORATED • TARRYTOWN, NEW YORK



See us at booth 426, IRE Show.

## What to see at the Radio Engineering Show (Continued from page 142A)

- |   |              |
|---|--------------|
| <b>Firm</b>   | <b>Booth</b> |
| <b>Ward Products Corp., Div. of Gabriel Co.,</b><br>Cleveland 3, Ohio   | 332          |
| TV, auto, mobile communications antennae. Also special antennae designed for Government and industry.   |              |
| <b>Waterman Products, Co., Inc.,</b> Philadel-<br>phia 25, Pa.  | 29           |
| Oscilloscopes: Pocket Scopes, pulse scopes. Rayonic cathode-ray tubes.  |              |
| <b>Webster Chicago Corp.,</b> Chicago 39, Ill.  | 366          |
| Magnetic recorders (tape & wire), "fonographs," and "diskchangers."   |              |
| <b>W. M. Welch Mfg. Co.,</b> Chicago 10, Ill.   | S-22         |
| Duro-Seal Vacuum pumps with guaranteed vacuum of 0.1 micron in capacities ranging from 3/4 cu. ft. per minute (21 liters) to 10 1/2 cubic feet (300 liters) per minute. Also to be shown are the Dubrovin & McLeod Gauges.  |              |
| <b>Western Lithograph Co.,</b> Los Angeles 54,<br>Calif.  | 107          |
| Our complete line of E-Z Code wire markers, cable, conduit & pipe markers, Hydraulic line identification codes, contact Labels, etc.  |              |
| <b>Westinghouse Electric Corp.,</b> Pittsburgh<br>30, Pa., Bloomfield, N.J., Baltimore, Md.   | 65-69        |
| Instruments: Panel, switchboard, and portable. Air circuit breakers. (Electronic transformers, electric transformer components.) Magnetic alloys. Electronic tubes. Railroad radio communication equipment. Selenium rectifier battery chargers. Airborne Transformer Rectifiers. Motor starters. Motor sentinel. Control components; commercial and Hi-shock. Thermostats. Hypersil cores. |              |
| <b>Weston Electrical Instrument Corp.,</b> New-<br>ark 5, N.J.  | 393A         |
| Electronic test equipment, panel instru-<br>ments, sensitive relays, ac and dc portable<br>instruments, dc amplifier, Bimetallic ther-<br>mometers.   |              |
| <b>Wind Turbine Co.,</b> West Chester, Pa.  | 48           |
| Trylon antenna masts and ladder towers;<br>trylon rotary beam.  |              |
| <b>The Workshop Associates, Div. Gabriel<br/>Co.,</b> Needham, Mass.  | 39           |
| Micro-wave, mobile and point-to-point uhf<br>transmitting antennas, and high frequency<br>connectors.   |              |



### We Can Deliver—

automatic screw machine products work-  
ing at close tolerance on brass, cold  
rolled steel, stainless steel, and alumi-  
num; 1/32" up to 1 1/2" diameter capacity.

A well equipped plant of 30 Brown &  
Sharpe Automatic Screw machines is  
available with a large capacity to pro-  
duce a substantial volume—Also facili-

ties for doing all secondary operations.

We also manufacture Wire Formings,  
Wire Products and Special Machine  
Parts.

We would appreciate the opportunity of  
quoting on your requirements and in-  
cluding us in your mailing list for future  
inquiries.

Just send us your blueprints & samples.

## AMERICAN HINGE CORP.

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Specializing in Radio-Electronics since 1923

Microwave  
Assemblies,  
Radar Components,  
and Precision  
Instruments . . .  
manufactured to  
your Blueprints  
and Specifications.

### See us at BOOTH N-19

(SECOND FLOOR)

### National Convention of the I. R. E.

MARCH 3-6, 1952

GRAND CENTRAL PALACE  
NEW YORK CITY

**N.R.K. MFG. & ENGINEERING CO.**

5644-50 NORTH WESTERN AVENUE • CHICAGO 45, ILL. • LOngbeach 1-6973

## VISIT BOOTH 453

- OIL DIFFUSION PUMPS
- HIGH VACUUM EQUIPMENT
- EVAPORATED FILMS

A completely new line of frac-  
tionating and miniature pumps.  
Ideal for tubes and other high  
vacuum applications.

### OPTICAL FILM ENGINEERING CO.

2737 North Sixth St.  
Philadelphia 33, Pa.

## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

### Mercury Thyatron

A newly developed Mercury Thyatron tube capable of handling high dc voltages and current, was announced today by the Sheldon Electric Co., Div. Allied Electric Products, Inc., 76 Coit St., Irvington 11, N. J.



The mercury thyatron MT-1530 is a grid-control tube, commonly referred to as a "cutoff" or "trigger" tube. The peak anode voltage is 15,000 volts forward or 15,000 volts inverse. It can be built either as a negative or positive control tube.

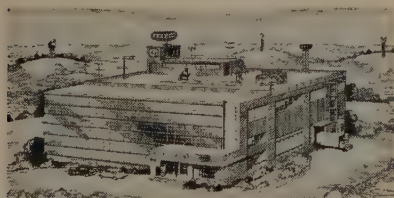
The MT-1530 has a completely shielded cathode structure. Of particular interest in its construction is the grid at the base of the upper half of the mercury-filled tube. It carries a guarantee for 1,000 hours.

This tube is a cathode filamentary type with a filament voltage of 5.0 volts, and a filament current of 30 amperes. The maximum plate current has a peak of 100 amperes, and an average of 15 amperes with a surge (maximum duration 0.1 sec.) of 1,500 amperes.

Sheldon stated in its announcement of the Thyatron, that it is prepared to manufacture other types of thyatrons, incorporating the features of its MT-1530, to meet the requirements of specific applications. Descriptive literature is available on request.

### New Laboratory

A new antenna laboratory will be erected by the Workshop Associates, Div. The Gabriel Co. The laboratory, to be located in Natick, Mass., is scheduled for completion in mid-1952.



The laboratory site is a 46-acre tract located approximately twenty miles from Boston. The roof will be specially designed for outdoor antenna work. Electrical

(Continued on page 152A)

# B&W Precise AUDIO TESTING

for designing, production checking, research or "proof of performance" FCC tests for broadcasters.

A low-distortion source of audio frequencies between 30 and 30,000 cycles. Self-contained power supply. Calibration accuracy  $\pm 3\%$  of scale reading. Stability 1% or better. Frequency output flat within 1 db, 30 to 15,000 cycles.

MODEL 200 . . . . . \$138



**AUDIO  
OSCILLATOR**

For fundamentals from 30 to 15,000 cycles measuring harmonics to 45,000 cycles; as a volt and db meter from 30 to 45,000 cycles. Min. input for noise and distortion measurements .3 volts. Calibration: distortion measurements  $\pm 5$  db; voltage measurements  $\pm 5\%$  of full scale at 1000 cycles.

MODEL 400 . . . . . \$168



**DISTORTION  
METER**

Combines RF detector and bridging transformer unit for use with any distortion meter. RF operating range: 400 kc to 30 mc. Single ended input impedance: 10,000 ohms. Bridging impedance: 6000 ohms with 1 db insertion loss. Frequency is flat from 20 to 50,000 cycles.

MODEL 404 . . . . . \$85



**LINEAR  
DETECTOR**

Speeds accurate analysis of audio circuits by providing a test signal for examining transient and frequency response . . . at a fraction of the cost of a square wave generator. Designed to be driven by an audio oscillator.

MODEL 250 . . . . . \$10



**SINE WAVE  
CLIPPER**

The instruments of laboratory accuracy

Bulletin PR-22 gives complete details

## Barker & Williamson, Inc.

237 Fairfield Avenue • Upper Darby, Pa.

• **DESIGNED**  
• **ENGINEERED**  
• **MANUFACTURED**  
for  
**PRECISION**  
**PERFORMANCE**



- 9999.9 hour range
- 10,000 hour automatic reset
- -55 to +55° C. operating temperature.



## RUNNING TIME METER

• Designed for use on AC lines where successful servicing of electronic or electrical equipment depends upon the regular servicing of such equipment based on actual operating (or idle) time. Unit has a range of 9999.9 hours and resets automatically at 10,000 hours. Can be supplied for either 120 or 240 volts. 60 cycle operation and has operating temperature of -55 to +55° C.

• The Running Time Meter is housed in Burlington's attractive, black bakelite 3" square or 3½" round case.

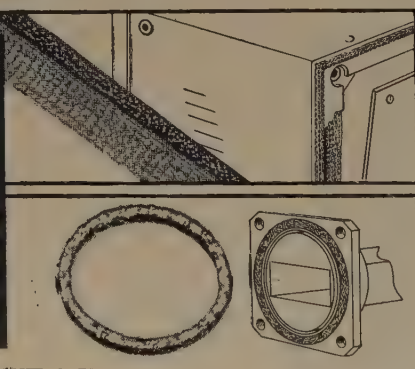
Write Dept. I-22 for further details.

## BURLINGTON INSTRUMENT COMPANY BURLINGTON, IOWA

See Us at Booth 228, I.R.E. Show

## SHIELDING PROBLEMS

effectively and economically solved with  
**METEX**  
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Benin, Z., 228 S. 12 St., Lewisburg, Pa.  
Boehmer, H. W., 100 Memorial Dr., Cambridge 42, Mass.  
Boyers, J. S., Magnecord, Inc., 225 W. Ohio St., Chicago, Ill.  
Clapp, F. D., 978 Grizzly Peak Blvd., Berkeley 8, Calif.  
Clelland, F. W., Jr., 188 Walter Hays Dr., Palo Alto, Calif.  
Crane, S. D., 2243 W. Morse Ave., Chicago 45, Ill.  
Foodim, C., 122 Richbell Rd., Mamaroneck, N. Y.  
Goff, L. O., Box 393-A, R.D. 5, Alexandria, Va.  
Joshi, C. P., Communication Center, Police W/T Section, Dilkusha Rd., Lucknow (U.P.) India  
Liebscher, A., 252 Wyncote Rd., Jenkintown, Pa.  
Lynch, W. A., 169 Ferncroft Rd., Mineola, N. Y.  
Macdonald, A. A., 216 Montrose Ave., Catonsville 28, Md.  
Marsh, K. W., 67 Oakland Ave., Port Washington, N. Y.  
McCann, F. H., 4415 N.E. 81, Portland, Ore.  
McCarley, H. H., Quarters LL, U. S. Naval Base, Charleston, S. C.  
Meadows, F. D., 1449 N. Emerson, Indianapolis, Ind.  
Meyers, J. G., 1056 Sheridan Ave., New York 56, N. Y.  
O'Connor, D. G., 48 Ashland Ave., Baldwin, L. I., N. Y.  
Owen, E. A., 301 Delafield Pl., N.W., Washington 11, D. C.  
Petkovsek, J. C., 1832 Liberty, Beaumont, Tex.  
Pischel, E. F., 5150 Genesta Ave., Encino, Calif.  
Rider, F. E., 1810 Alamanda Dr., Miami 38, Fla.  
Schreiner, L. W., 122 Park Lane Ave., Chicago 31, Ill.  
Shoemaker, J. R., 1428 Riverview Terr., Alexandria, Va.  
Smith, B., Jr., 1831 Ohio Ave., Cuyahoga Falls, Ohio  
Smith, W. L., 10110 Pierce Dr., Silver Spring, Md.  
Sodaro, J. F., 3505 Purdue Ave., Los Angeles 34, Calif.  
Staples, E. B., Cambridge Research Laboratories, 230 Albany St., Cambridge, Mass.  
Treuhaft, M. A., 1809 Manor Dr., Union, N. J.  
Welsh, W. A., 1823 Elizabeth Ave., Winston-Salem 7, N. C.  
Wheeler, B. F., 600 Cedar Ave., Haddonfield, N. J.  
White, G. R., Bendix Radio, E. Joppa Rd., Towson 4, Md.

### Admission to Senior Member

- Anderson, E. W., 19 Edgebury, Chislehurst, Kent, England  
Arthur, M. A., 209 Humble Bldg., Houston 2, Tex.  
Blye, P. W., Bell Telephone Laboratories, Inc., 463 West St., New York 14, N. Y.  
Engelmann, H. F., 165 Laurel Hill Rd., Mountain Lakes, N. J.  
Fisk, J. B., Bell Telephone Laboratories, Inc., Murray Hill, N. J.  
Harrigan, G. S., 3800 W. Cortland St., Chicago 47, Ill.  
Monack, A. J., Box 305, Rutherford, N. J.  
Muirhead, C. R., 48-42 Ave., Lachine, Que., Canada  
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(Continued on page 148A)

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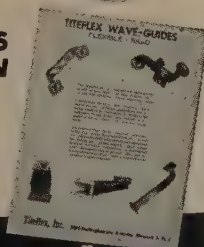
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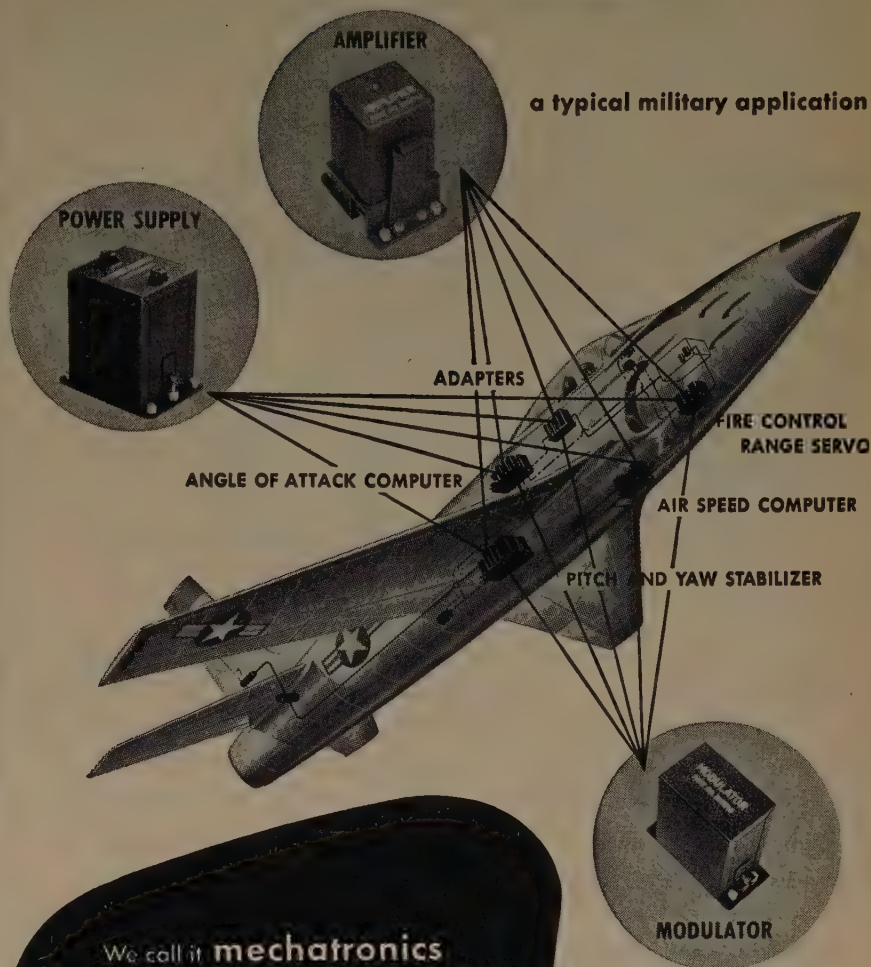
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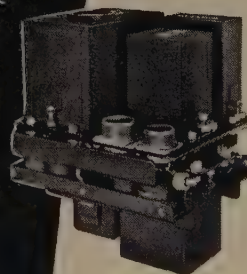
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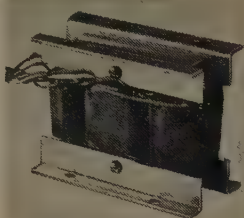
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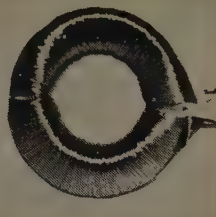
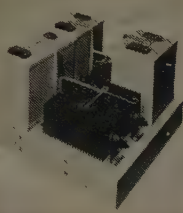
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W. 7, England

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N. Y.  
Byrne, R. M., 316 Melbourne Ave., Akron 3, Ohio  
Bubb, A. H., 114 Haas Ave., Sunbury, Pa.  
Buchholz, W., c/o Vincent, R. D. 4, South Rd.,  
Poughkeepsie, N. Y.  
Burke, J. T. 2580—23 St., Cuyahoga Falls, Ohio  
Caulkins, F. A., 1706 Thornapple Ave., Akron, Ohio  
Craine, L. B., Electrical Engineering Department,  
University of Idaho, Moscow, Idaho  
deMacedo, A., Jr., Rua Martim Francisco 382, Sao  
Paulo, Brazil  
Ebbeler, J. R., N. College Hill, 7030 Ellen Ave.,  
Cincinnati, Ohio  
Forsman, E. H., 3609 E. 34 Ave., Denver, Colo.  
Freeman, H., Mail Sta. EX 31, Sperry Gyroscope  
Company, Great Neck, L. I., N. Y.  
Gray, D. W., R.D. 7, N. Canton, Ohio  
Haehnle, C. G., 6310 Stover Ave., Cincinnati 13,  
Ohio  
Harding, E. W., Rm. 119, Ballistic Research  
Laboratories, Aberdeen Proving Ground,  
Md.  
Harmon, R. C., Harmon Electronics Company,  
11431 Truman Rd., Independence, Mo.  
Havel, J. M., 449 Branch Ave., Little Silver, N. J.  
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Canada  
Haywood, V. M., 228 Newport News Ave., Hamp-  
ton, Va.  
Horn, H. S., 186 Massachusetts Ave., Cambridge  
39, Mass.  
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Johnson, R. A., Box 869, Melbourne, Fla.  
Jones, J. W., 35 Frederick Ave., Akron 10, Ohio  
Kantor, G., 98-34—63 Dr., Forest Hills, L. I.,  
N. Y.  
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Mo.  
Melton, D. P., 1023 Gardenia Dr., Houston 18,  
Tex.  
Morrison, H. L., Mt. St. Michael's, Spokane 28,  
Wash.  
Rao, J., Research Department, Pye Ltd., Radio  
Works, Cambridge, England  
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N. Y.  
Robinson, G. C., 4273 Shorecrest Dr., Dallas 9,  
Tex.  
Scharla-Nielsen, H., c/o Radiation, Inc., P. O.  
Drawer Q, Melbourne, Fla.  
Schipper, R. J., 31 Greenbrier Ave., S. Ft. Mitchell,  
Ky.  
Spitzer, C. F., 243 Buckingham Ave., Syracuse 10,  
N. Y.  
Sterling, S., 13331 Linwood Ave., Detroit 6, Mich.  
Stockard, L. C., 1390 Lucas Dr., Beaumont, Tex.  
Swafford, J. E., 10 Chichester Ave., East Hampton,  
Va.  
Taishoff, J., Savoy Plaza Hotel, 58 St. & Fifth  
Ave., New York, N. Y.  
Walker, H. E., 3227-M—34 St., Sandia Base,  
Albuquerque, N. Mex.  
Werth, M. W., 5809 Kenwood Ave., Baltimore 6,  
Md.  
West, J. P., 4646—31 Rd., S., Arlington 6, Va.

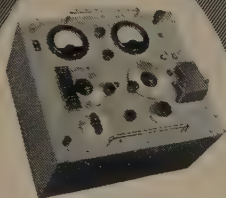
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Bartlett, T. L., RCA, 30 Rockefeller Plaza, New  
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(Continued on page 149A)

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 Child, C. H., 7326 E. Grove Ave., Paramount, Calif.  
 Cockburn, C. D., R.D. 3, West River Rd., Baldwinsville, N. Y.  
 Coffin, W. R., 2947 Russett Ave., Dayton 4, Ohio  
 Cole, H. W., 92 Anderson Pkwy., Cedar Grove, N. J.  
 Coleman, D. L., Jr., Frost Rd., Ashby, Mass.  
 Collins, M. F., 5109 Tomahawk Rd., Mission, Kans.  
 Council, J. W., 711 Granby St., Norfolk 10, Va.  
 Dollinger, K., 381 Central St., West Acton, Mass.  
 Evans, W. E., Apt. II, Onondaga Pkwy. Apts., Liverpool, N. Y.  
 Gartner, J. J., 2-10 Main St., Little Ferry, N. J.  
 Gifford, R. P., 120 Dewittshire Rd., Dewitt, N. Y.  
 Hagopian, R. H., 5514 Ashbourne Rd., Baltimore 27, Md.  
 Harrington, D. J., 10 Cottage Hill Rd., Glen Falls, N. Y.  
 Jahr, E. F., 1428 Ohio, Lawrence, Kans.  
 Kennedy, W. H., 11 Hill, Alplaus, N. Y.  
 Lesinsky, F., 638 Philip, Detroit 15, Mich.  
 Lipson, W., 98 Hancock Ave., Franklin Square, L. I., N. Y.  
 McCone, G. L., 6222 Victoria Ave., Los Angeles, Calif.  
 Mrazek, W. F., 1435 S. Gunderson Ave., Berwyn, Ill.  
 Oliver, J. R., 15717-C Halldale Ave., Gardena, Calif.  
 Parkins, F. A., 28 Avery Dr., N.E., Atlanta 5, Georgia  
 Peeler, G. D. M., 5600 Longfellow St., East Riverdale, Md.  
 Peifer, A. G., Federal Telecommunication Laboratories, Inc., 500 Washington St., Nutley, N. J.  
 Pinnell, S. E. A., 48 Academy Rd., Westmount, Que., Canada  
 Pollack, I. H., 7600 N. Greenview, Chicago 26, Ill.  
 Raser, E. G., 315 Beechwood Ave., Trenton 8, N. J.  
 Rasmussen, A. R., 1511 Fort David Pl., S.E., Washington, D. C.  
 Richards, R. S., P.O. Sub. 18, Clarke Side Rd., London, Ont., Canada  
 Rolland, S. F., Durban Radio, Kloof, Natal, South Africa  
 Schimmel, J., III, 150 Main St., Williamstown, Mass.  
 Seaver, G. E., c/o L. W. Baldwin, Gilmore City, Iowa  
 Skinner, G. M., Linde Air Products Co., E. Park & Woodward Aves., Tonawanda, N. Y.  
 Soja, M., 4614 Alexander Dr., Ft. Wayne, Ind.  
 Spradlin, J. D., 614 Charles St., Mt. Ephraim, N. J.  
 Stafford, B. H., 118 Rolph Dr., S.W., Forest Heights, Washington 20, D. C.  
 Stanley, C. B., 920 Wilbur St., Salem, Ore.  
 Stein, N., 1205 Walnut St., Uniondale, N. Y.  
 Steiner, W. L., 2576 Ninth St., Cuyahoga Falls, Ohio  
 Thompson, W. B., 410 W. Pine St., Shamokin, Pa.  
 Tinkler, R. F., Manitoba Telephone System, 166 Portage Ave., E., Winnipeg, Man., Canada  
 Turner, B. S., Chicago Telephone Supply Corporation, 1142-1232 W. Beardsley Ave., Elkhart, Ind.  
 Vogel, N. I., 1108 Elgin Terr., Montreal 2, Que., Canada  
 Wagenhals, E. R., 177 Gaylor Rd., Scarsdale, N. Y.  
 Whelan, C. R., Massachusetts Institute of Technology, 77 Massachusetts Ave., Cambridge, Mass.  
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(Continued on page 150A)

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(Continued from page 149A)

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Anderson, N. Y., 219 Center St., E. Aurora, N. Y.  
Axtell, J. C., Southwest Research Institute, San Antonio, Tex.  
Barclay, C., 2031 Industrial Bldg., National Bureau of Standards, Washington 25, D. C.  
Becher, W. D., 240 E. 32 St., Paterson, N. J.  
Beck, S. A., 2145 Emmons Ave., Dayton, Ohio  
Beebe, J. A., CAA, 5-55941, Rm. 2401, City Hall Bldg., Kansas City, Mo.  
Bendazzi, A., 71-50 Austin St., Forest Hills, L. I., N. Y.  
Birely, L. S., Jr., J.H.U. Radiation Laboratory, 1315 St. Paul St., Baltimore, Md.  
Bouquet, F. L., Jr., Sanger Rd., Bldg. 2040, Apt. 38, Fort Monmouth, N. J.  
Brett, E. D., 1411 Fourth Ave. Bldg., Suite 425, Seattle 1, Wash.  
Briggs, F. F., 3358 Prairie, Royal Oak, Mich.  
Brown, O. C., Jr., 54 Pine, Malden, Mass.  
Bruns, C. R., 412 Schuyler Dr., Dayton, Ohio  
Brust, M. F., 6312 Darwood, Fort Worth 7, Tex.  
Burt, C. A., 9049 Ft. Hamilton Pkwy., Brooklyn, N. Y.  
Byrne, G. C., 8 Miles Rd., Mimico, Ont., Canada  
Carlos, J. B., 90-15—180 St., Jamaica 3, L. I., N. Y.  
Caruana, P. A., 122 Penn Ct., Fort Worth, Tex.  
Christie, G. A., 151 N.W. 92 St., Miami 38, Fla.  
Cote, E. P., 61 Stewart St., Ottawa, Ont., Canada  
Courtney, W. R., 2619 Alice St., Los Angeles 65, Calif.  
Cox, B. O., 1327 N. Parkside, Chicago 51, Ill.  
Cretella, S. A., 102-50—62 Dr., Forest Hills, L. I., N. Y.  
Cunningham, J. B., R.D. 2, Box 167-F, San Antonio, Tex.  
Dale, J. C., 29-D Savannah Terr., North Augusta, S. C.  
DeLuca, L. A., Box 632, AA & GM TAS, Ft. Bliss, El Paso, Tex.  
Dennis, J. R., 5327 E. Fourth St., Tulsa 12, Okla.  
DeSarno, F. R., 115 Goldie Ave., North Bellmore, N. Y.  
Eiting, H. J., 839 Loomis St., Jackson, Mich.  
Elion, H. A., 46 Iark Lane, N., Franklin Square, L. I., N. Y.  
Eri, D. G., 818 Sixth Ave., N.W., Minot, N. Dak.  
Fredricks, L., 21-14—28th St., Astoria, L. I., N. Y.  
Gardiner, S. R., 19988 San Juan Dr., Detroit, Mich.  
Glaser, P. R., 1275 E. Fifth St., Brooklyn 30, N. Y.  
Goddard, W. A., 330 W. Fairview Blvd., Inglewood, Calif.  
Goodman, K. E., Radio Station WTOG, 516 Abercorn St., Savannah, Ga.  
Gross, R. J., 214 Oxford St., Guelph, Ont., Canada  
Haas, A. N., 2308 Belvoir Blvd., University Heights, Ohio  
Haddon, P. E., 28 McOwen St., Dayton 5, Ohio  
Haggstrom, R. W., 327 S. Lewis Ave., Lombard, Ill.  
Halonon, C. A., R.R. 4, Xenia, Ohio  
Hammond, E. K. F., 64 Fulton Ave., Toronto, Ont., Canada  
Handa, V. P., 23 Kutchi House, Brahman Wada Rd., Bombay, India  
Heal, J. A., RCAF Station, Clinton, Ont., Canada  
Heffner, H. A., R.R. 1, Tipp City, Ohio  
Heller, C. J., 1521 Kipling Dr., Dayton 6, Ohio  
Henderson, E. C., 617 E. Randolph St., Angola, Ind.  
Hines, C. A., Box 465, R.R. 2, Fairborn, Ohio  
Janke, E. W., 6920 Simpson Ave., N. Hollywood, Calif.  
Jennings, B. B., 110-B Bear St., St. Andrews Homes, Charleston, S. C.  
Kampe, E. A., 409 Ramona Dr., El Paso, Tex.  
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 Kilburn, A. B., Box 222, Sunbury, Pa.  
 Kirby, R. L., USAF Institute of Technology, Wright-Patterson AFB, Dayton, Ohio  
 Kirkevold, C. R., 790 Clermont, Denver 20, Colo.  
 Kirvada, L., 102 Irvington St., S.W., Washington 20, D. C.  
 Klerk, R. H., 968 Maple Dr., Franklin Square, L. I., N. Y.  
 Kolta, R. C., 157 W. Apsey St., Philadelphia 44, Pa.  
 Korf, S., 29 Corbin Pl., Brooklyn 35, N. Y.  
 Kretz-Muller, Schonauring 83, Zurich 11-52, Switzerland  
 Kruger, F. W., Box 863, Vallejo, Calif.  
 LaFreniere, P. J., 61 Sherman Apt. 3, Ottawa, Ont., Canada  
 Larkin, L. K., International General Electric Company, 576 Lexington Ave., New York 22, N. Y.  
 Laurey, A. S., 1418 Kemble St., Utica, N. Y.  
 Leezio, N. J., 6600 Wellington, Chicago 34, Ill.  
 MacDonald, A. H., 1 Kenmore Rd., Valley Stream, L. I., N. Y.  
 Mallison, R. E., 1001 N. Second Ave., Alpena, Mich.  
 Martin, W. C., 5141 Walker Way, El Paso, Tex.  
 Mayer, A. P., 1928 Fourth Ave., S.E., Cedar Rapids, Iowa  
 McLennan, D. E., 2191 W. First Ave., Vancouver, B. C., Canada  
 Meyer, F., 708 Anderson Ave., Franklin Square, L. I., N. Y.  
 Miller, W. A., 1667 W. First St., Brooklyn 23, N. Y.  
 Mischler, G. J., Box 7166, Dallas 9, Tex.  
 Mowbride, P. E., 1614-19 St., Mason, Iowa  
 Nayar, T. P. C., National Institute of Engineering, Hoshiarpur, Punjab 1, India  
 Novak, E. K., 6430 S. Talman Ave., Chicago 29, Ill.  
 Olson, P. C., 519-32 St., N.E., Cedar Rapids, Iowa  
 Peck, F. K., R.D. 2 Box 159-C, Kennewick, Wash.  
 Perry, R. A., 1723 Harvard Ave., Independence, Mo.  
 Petranek, D. J., US 55100558, Svc. Con. c/o TV Caravan, Fort Monmouth, N. J.  
 Pitzer, J. F., 8 Kiernan Blvd., North Long Branch, N. J.  
 Publicover, A. M., 40 Earl Gray Rd., Toronto, Ont., Canada  
 Pyle, J. C., 1511 Alton, Denver 8, Colo.  
 Rajendra, Y. L., Ganesh Bhawan Agra Rd., Nank City, Nank, India  
 Rastier, D. B., Box 523, Holdingsford, Minn.  
 Robertson, O. Z., Jr., Third Radio Squadron, M., APO 942, c/o PM, Seattle, Wash.  
 Robson, A. B., Jr., Philco Corporation, 22 St. & Lehigh Ave., Philadelphia 32, Pa.  
 Saxon, W. R., 304 W. Vernon Ave., Phoenix, Ariz.  
 Schreiber, P. W., 940 E. Central Ave., Mansburg, Ohio  
 Sentell, F. N., R.F.D. 1, Uncasville, Conn.  
 Stoffer, P. A., Jr., 1844 Bridget Rd., Pasadena 7, Calif.  
 Stekel, J., 8 Ben Yehuda St., Haifa, Israel  
 Shukhtsina, D. C., 24 Briarduff Rd., Charleston 45, S. C.  
 Silberfarb, E., 13A Simmel St., Haifa, Israel  
 Singer, L. H., 43-09-43 St., Long Island City, L. I., N. Y.  
 Singh, B., National Institute of Engineering, Hoshiarpur, Punjab, India  
 Slad, G. F., 2241 S. Austin Blvd., Owens 50, Ill.  
 Smith, J. N., 30 Sawbridge Ave., Westmont, Collingswood, N. J.  
 Snodgrass, M. L., Midwest Research Institute 4649 Pennsylvania, Kansas City 2, Mo.  
 Soren, L. T., 2000, Westman Rd., Silver Spring, Md.

(Continued on page 152A)

# STANDARD Radio Interference and Field Intensity MEASURING EQUIPMENT

Complete Frequency Coverage -- 14kc to 1000mc!



**NM-10A VLF**

14kc to 250kc  
 Commercial Equivalent of  
 AN/URM-6.  
 Very low frequencies.



**HF NM-20A**

150kc to 25mc  
 Commercial Equivalent of AN/PRM-1.  
 Self-contained batteries. A.C. supply  
 optional. Includes standard broadcast  
 band, radio range, WWV, and commun-  
 ications frequencies.



**NMA-5A VHF**

15mc to 400mc  
 Commercial Equivalent of  
 TS-587/U.  
 Frequency range includes  
 FM and TV Bands.



**UHF NM-50A**

375mc to 1000mc  
 Commercial Equivalent of  
 AN/URM-17.  
 Frequency range includes Citizens  
 Band and UHF color TV Band.

These instruments comply with test equipment requirements of  
 such radio interference specifications as JAN-I-225a, ASA C63.2,  
 16E4(SHIPS), AN-I-24a, AN-I-42, AN-I-27a MIL-I-6722 and others.

**STODDART AIRCRAFT RADIO CO.**  
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# MICROPOT      PRECISION TEN-TURN MICRODIAL      POTENTIOMETER PRODUCTION      TEN TURN-COUNTING HAS BEEN DOUBLED!      DIAL

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Manufacturing facilities for the famous Borg Micropot and Microdial have been doubled. This Janesville plant of The George W. Borg Corporation has been expanded to meet your requirements.

**NOW . . .** improved service and earlier delivery dates are assured to all our Micropot, Microdial customers.

THE BORG EQUIPMENT DIVISION  
OF THE GEORGE W. BORG CORPORATION  
JANESVILLE, WISCONSIN



(Continued from page 151A)

Sommer, J. G., Jr., 5413 Wehawken Rd., Washington 16, D. C.  
Speciale, J. S., Atlanta, Ill.  
Spychalski, J. A., 937 Hare Ave., Westboro, Box G-1, Ottawa, Ont., Canada  
Stone, O. L., 4007-B Arizona Ave., Los Alamos, N. Mex.  
Thomas, H. B., Box 245, Folly Beach, S. C.  
Thrasher, P. J., 4831 Barclay Ave., Apt. 1, Montreal, Que., Canada  
Uskavitch, C. W., 33½ Main St., Potsdam, N. Y.  
Vallance, G., 3256 W. 27 Ave., Vancouver, B. C., Canada  
Wadsworth, N. L., 225 Audubon Park, Dayton 7, Ohio  
Wagner, F. D., Jr., 3739 Modlin St., Fort Worth, Tex.  
Walecki, V., 1288 S. 50 St., Philadelphia, Pa.  
Warszawsky, L. M., 1422 Chadwick, Dr., Dayton 6, Ohio  
Watstein, L., 43-33—46 St., Long Island City, L. I., N. Y.  
Weinberg, E. F., Philco Tech. Rep. Box 632, AA & GM BR TAS, Fort Bliss, Tex.  
Zimmerli, R. B., The Polymer Corp. of Pennsylvania, Reading, Pa.  
Zito, P. J., 5363 Harding, Detroit 13, Mich.

## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 145A)

engineering, mechanical engineering, model shop, and a drafting department will all be located in the laboratory, together with all engineering offices for the Workshop Associates.

As the first industrial laboratory to be designed primarily for antenna research, the building will have many unique refinements. In addition to the special roof design, the large area available will permit several distant pattern ranges. It is planned to have a separate range for each of the most commonly used frequencies. Special pattern measuring equipment and other electronic equipment has been designed by Workshop engineers to further complement laboratory facilities. Complete mechanical test facilities will also be included.

## Facsimile for Industry

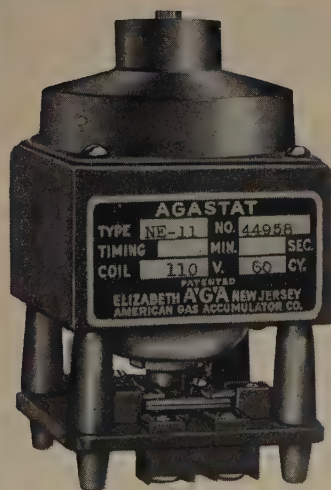
Alden Products Co., 117 North Main St., Brockton 64, Mass., announced at the A.I.E.E. meeting in New York that early this fall new high-speed facsimile equipment will be available for business.

This equipment makes possible taking letters, drawings, orders, and reproducing a copy or copies in any other department or departments no matter where located, making possible the sending of a letter size sheet in a little over thirty seconds.

Designed for business use, it can eliminate messengers, internal expeditors, and stock chasers. It should be of great value in order processing, credit, or production control where (in ordinary business) names, addresses, and much information common to control forms are recopied many times. In control centers using Alden

(Continued on page 153A)

# easily mounted



in any position, altho designed for vertical mounting. Back mounting or front mounting.

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# AGASTAT

TIME DELAY RELAY for every requirement

**AGA**

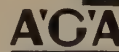
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AGASTAT  
TIME DELAY  
RELAY



STIMSONITE  
REFLECTORS



AIRPORT  
LIGHTING



MARINE  
LIGHTING  
EQUIPMENT

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 152A)

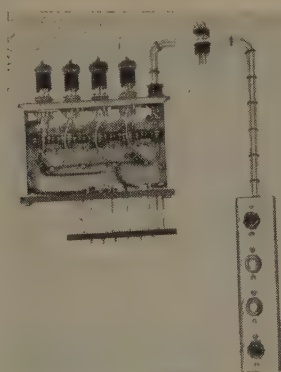
Facsimile, common information is copied by the Facsimile without reorganizing.

The equipment takes up little room 14 inches X 32 inches of floor space for both sending and receiving equipment. It can be mounted in standard desks. A clerk can operate it by merely switching on, and inserting the copy to be sent. The equipment described is designed to be serviced by changing any of the elements for a replacement unit (in less than 30 seconds). This can be done by unskilled personnel, and all replacement units are small enough in weight or size to be mailed by parcel post.

The equipment discussed is in part the result of Navy development contracts carried on by the Alden Products Co., Brockton, and is to be made and distributed by the Alden Systems Co., Alden Research Center, Westboro, Mass.

## Miniaturized Electronic Counter Decades

The Potter Instrument Co., Inc., 115 Cutter Mill Rd., Great Neck, L. I., N. Y., announces a new miniaturized version of its four-tube Electronic Counter Decade. The redesign, which is approximately one-third smaller than the size of the standard decade, is available in two models which differ only in the maximum counting capabilities. Model 12 is designed for counting at rates up to 130,000 counts per second and Model 13, for counting at rates up to 30,000 counts per second.



There is four-lamp decimal indication, and since each of the four lamps is directly connected to one of the four counting stages, the lamps also serve to indicate that the associated stages are functioning correctly; therefore tube failures can be detected. In addition, the counter stages are arranged so that the progression of count can not skip over a stage in which a tube failure has occurred.

The new miniaturized decades are available with either a remote panel-mounted four-lamp readout or with a small plug-in neon cluster on the decade frame for applications in which the indicators serve only for tube servicing.

The size of the new unit is 6½ inches long, 6½ inches high, and 1½ inches wide including tubes.

(Continued on page 169A)

## TO MEET MIL-T-27 SPECIFICATIONS

# Stancor Transformers

**MUST OPERATE PROPERLY AFTER EXPOSURE TO THESE EXTREME PHYSICAL CONDITIONS**

### TEMPERATURE CYCLING

**Step One** 1—15 minutes at 185° F (85°C).

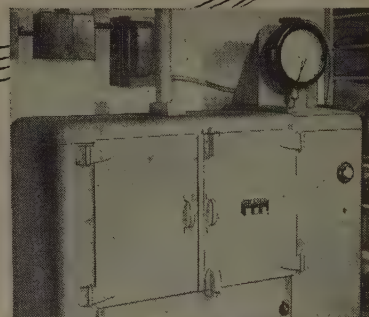
**Step Two** 2—15 minutes at room temperature.

**Step Three** 3—15 minutes at -67°F (-55°C).

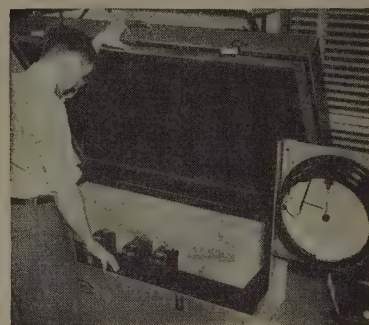
**Step Four** 4—15 minutes at room temperature.

**Step Five** 5—15 minutes in saturated salt bath.

These steps are repeated for five consecutive cycles and the unit is then subjected to a dielectric strength test at 100% of the specified voltage for five (5) seconds and the insulation resistance checked.



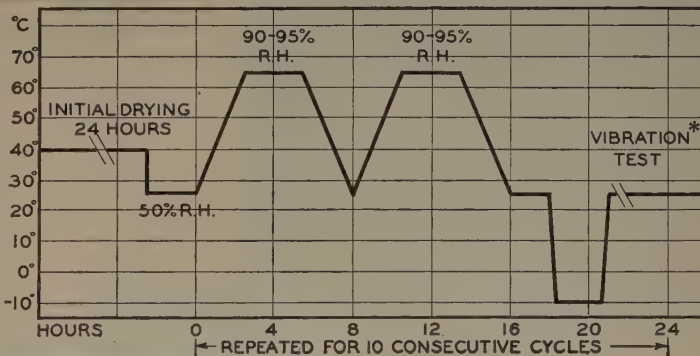
OVEN



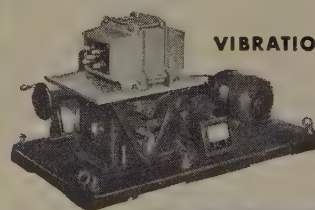
COLD CHAMBER

### HUMIDITY CYCLING

\*At the end of any 5 cycles the unit is removed from the humidity chamber and subjected, for 15 minutes, to simple harmonic motion of 0.03" amplitude, with the frequency varying uniformly from 10 to 55 CPS and return to 10 CPS in one minute.

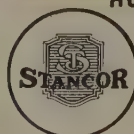


HUMIDITY CHAMBER



VIBRATION TABLE

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## STANDARD UNITS AND SPECIFICATIONS



**Nobatron  
Model E-6-15**

**AC Regulator  
Model 500S**



**Nobatron  
Model SWR-5**



**B-Nobatron  
Model 500BB**



**Ranger  
Model SR-100**

### AC REGULATORS

Models available  
(numbers denote  
VA capacities)

150S  
250S  
500S (-2S) also  
1000S (-2S) also  
2000S  
3000S (-2S) also  
5000S (-2S) also  
10000S (-2S) also  
15000-2S

### NOBATRONS\*\* (DC Supplys—low voltage)

Models available  
(numbers indicate  
voltage & current)

E-6-5A  
E-6-15A  
E-6-40A  
E-6-100A  
E-12-5  
E-12-15  
E-12-50  
E-28-5  
E-28-10  
E-28-30  
E-28-70  
E-28-150  
E-28-350  
E-125-10  
E-200-5

Also Model  
SWR-5 with  
output either  
6VDC @  
10 amp  
or  
12VDC @  
5 amp

### 400~ EQUIPMENT:

#### LINE REGULATORS

#### NOBATRONS\*\*

#### B-NOBATRONS\*\*

(DC Supplys—  
high voltage)

Input	95-130 VAC, 1 $\Phi$ , 50-60~, 190-260 VAC in "-2S" models
Output	115 VAC $\pm$ 5%; 230 VAC with "-2S" models
Reg. accuracy	$\pm$ 0.1% against line or load
Distortion	2% — 3% max.
P. F. range	Down to 0.7
Load range	0 to full load
Miscellaneous	Fully protected against overload or over-voltage. Models 150S, 250S, 500S, 1000S, 5000S, 10000S, and 15000-2S are self-contained. Cabinets available for others.
Input	95 — 130 VAC, 1 $\Phi$ , 50-60~. In heavy current 28-volt series — 115/208, 3 $\Phi$ , 4-wire, wye.
Reg. accuracy	$\pm$ 0.2% against line or load changes
Ripple	1% RMS max.
Load range	1/10 to full load
Output range	Adjustable $\pm$ 10%; down to —25% at lesser accuracy
Recovery time	0.2 seconds — this value includes charging time of filter circuit for most severe change in load or input conditions.
Miscellaneous	Fully protected against overload and over-voltage. Normally for rack mounting — cabinets available. Normal finish — gray wrinkle. Meters standard in some models; available in all.
Note	"A" models output either 6 or 7 volts.

Similar to 60~ regulators except:  
Accuracy  $\pm$ 0.5%; distortion 5% max.;  
VA capacities 250, 500, 1200, 2500.

Same general specifications as 60~ Nobatrons.  
Models 6VDC @ 40 amp., 12VDC @ 10 amp.,  
28VDC @ 10 amp.

Input	105-125 VAC, 1 $\Phi$ , 50 — 60~.
Load range	0 — full load
Ripple	10 mv (20 mv in 1000BB)

output	Model	325BB*	360BB**	500BB*	520BB**	560BB*	1000BB*
	VDC	0-325	175-360	0-500	200-500	0-500	200-1000
	Ma	0-125	0-120	0-300	0-200	0-200	0-500

\* meters furnished as standard equipment.  
regulation accuracy  $\pm$ 0.5%  
bias supply 0-150 VDC @ 0-5Ma (except model 1000BB)

\*\* no meters, no bias supply  
regulation accuracy  $\pm$ 1.0%

All have 6.3 VAC, 6-10 amperes, unregulated, C.T.  
except Model 1000BB.

\*"Isotronic" is a registered trademark denoting the electronic regulation and control of voltage, current, power, and frequency.

\*\* Reg. U. S. Pat. Off. by Sorensen & Co., Inc.

See the Isotronic Line at the  
I.R.E. Show—Booths 236 and 237

## STANDARD UNITS AND SPECIFICATIONS

<b>RANGERS</b>  (Full-range-variable DC Supplies)	Input range	95 — 130 VAC, 1 $\Phi$ , 50 — 60~.			
	Reg. accuracy	$\pm 0.25\%$ at any voltage setting.			
	Ripple	1% RMS max.			
	Output	Model	SR-100	SR-30	SR-2
		VDC	3-135	3-30	100-300
		Amps	1-10	3-30	1-10

## ISOTRONIC EXCLUSIVES

Super-accurate AC Line Regulator Model 1001	Load range	0 — 1000 VA
	Input volt. range	95 — 130 VAC, 1 $\Phi$ , 55 — 65~.
	Load P. F. range	0.7 lagging to 0.95 leading
	Output voltage	115 VAC, 1 $\Phi$ (adjustable from 110-120 volts)
	Distortion	3% max.
	Time constant	0.1 seconds
	Reg. accuracy	$\pm 0.01\%$
DC Power Source for Spectrophotometers Model E-6/2-5 Nobatron	Input volt. range	95-130 VAC, 1 $\Phi$ , 50-60 cycles
	Output	
	#1 for lamp	6VDC adjustable $\pm 10\%$ at 5 amperes
	#2 for filament	6VDC at 100 Ma.
	#3 for bias	2VDC adjustable $\pm 10\%$ at 100 Ma.
	Filtering	
	#1	1% max.
	#2 & 3	0.05% max.
	Reg. accuracy	$\pm 0.01\%$ against line changes
	Time constant	0.1 seconds under most severe line changes
Frequency Changer Model 3FCD250	Input voltage	95-130 VAC, phase to neutral, 3 $\Phi$ , 4 wire
	Input frequency	45-65 cycles
	Output voltage	115 VAC, 1 $\Phi$ , adjustable between 110-120 VAC
	Output frequency	400 cycles $\pm 10\%$
	Output voltage regulation	$\pm 1.0\%$
	Output frequency regulation	$\pm 1\%$ in standard model $\pm 0.01\%$ with auxiliary frequency standard
	Capacity	250 VA
	Load range	0.1 to full load
	Distortion in output	5% maximum
	P. F. range	Down to 0.7 P. F. lagging
	Time constant	0.25 seconds
	Envelope modulation	2% maximum

A single phase input model is also available.



## COAST TO COAST

Authorized Sorenson representatives and their field engineers are listed below. Find the one located nearest you — don't hesitate to call on him for consultation and advice.

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### CALIFORNIA — SAN FRANCISCO

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### D.C. — WASHINGTON

Burlingame Associates — F. L. Horman  
2017 S St., N.W.; Phone Decatur 8000

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P. O. Box 466; Phone 5-6762

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817 Citizens Bldg.; Cleveland, Ohio

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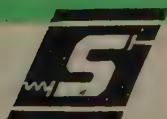
Earl W. Lipscomb & Associates  
2420-B Rice Blvd.; Phone Linden 9303

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### ENGINEER

Transformer and electronic specialty firm in upstate New York, anxious to hire engineer experienced in the design of transformers for communication equipment. Salary and opportunities for advancement will be commensurate with the man's ability. Box 682.

### SALES ENGINEER

Young engineer wanted to handle sales inquiries and to call on industrial customers in

(Continued on page 158A)



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Servomechanisms  
Telemetry  
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*"The Boeing Flying Forts came through a wall of flak and fighters that night to hit Berlin right on the nose. They never let us down—not then or on any of the raids to come. I was proud to fly the old Boeings. Now I'm prouder still to be on the great engineering team that designs the new ones."*

Boeing engineers feel that way. And they'd be honored to have you join them as they pioneer in dramatic new fields of aviation. There are excellent openings in Seattle now for experienced and junior aeronautical, mechanical, electrical, electronics, civil, acoustical, weights and tooling engineers for design and research; for servo-mechanism designers and analysts; and for physicists and mathemati-

cians with advanced degrees. Or, if you prefer the Midwest, there are similar openings at the Boeing Wichita, Kansas, Plant. Inquiries indicating a preference for Wichita assignment will be referred to the Wichita Division.

The steady growth of Boeing's Engineering Division over the past 35 years is an index of stability. There's great work to be done in all phases of aircraft design . . . in the fascinating new field of guided missiles . . . in jet propulsion.

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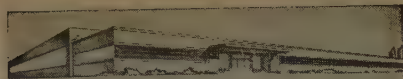
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Boeing Airplane Company, Seattle 14, Wash.  
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(Continued from page 156A)

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### DEVELOPMENT ENGINEERS, PHYSICISTS, MATHEMATICIANS

Massachusetts Institute of Technology's Digital Computer Laboratory, Dept. of Electrical Engineering has staff openings for research and development engineers, physicists, and mathematicians, either with or without experience, for work involving logical design, theoretical analysis, component and circuit research and development (including work on transistors, ferromagnetic and ferroelectric memory cells, magnetic drums, transmission of coded information, and analog-digital conversion). Persons transferring from other fields to acquire experience in digital computers for engineering and military uses are encouraged to apply and may come on leave of absence from their permanent organizations. Position carries opportunity for academic study. Salary appropriate to candidate's experience and training. Address: Digital Computer Laboratory, MIT, 211 Mass. Ave., Cambridge 39, Mass.

### PROJECT ENGINEER

Research lab. with excellent wind tunnel facilities needs project scientist with M.S. or Ph.D. in Aero. Eng. and minimum of 5 years' experience to conduct project groups in studies of aerodynamic research problems. Opportunity for man interested in pursuing further graduate study. Modern housing available at \$55 per month. Liberal employee benefits. Submit details of background to Mr. Francis Womack, Rosemount Research Laboratories, Rosemount, Minnesota.

(Continued on page 159A)

# ENGINEERS Electronic & Electro-Mechanical and DESIGNERS

Make Your Move In  
The Right Direction



## POSITIONS THAT POINT TO A SUCCESSFUL FUTURE!

### Minimum Requirements For ENGINEERS

Four years experience in advanced research and development on Radar Systems, Computers, Wave Guide and Antennas, Fire Control, Moving Target Indication, Servomechanisms, Pulse Techniques, Gyroscopic Equipment and Related Fields.

### Minimum Requirements For DESIGN ENGINEERS

Background-experience in design of Light Machinery, Radar Systems, Computers, Moving Target Indicators, Servomechanisms, Gyroscopic Equipment and Related Fields.

If Your Skills are now being fully utilized in a vital defense industry, please do not apply.

Kindly send resume and salary requirements to:

**The W. L. MAXSON  
CORPORATION**  
460 W. 34th ST.  
NEW YORK 1, N.Y.

# ENGINEERS

## Unusual Opportunities and Salaries

Exist on project and product engineering work for Graduate Engineers with Design, Development and Product experience in any of the following:

- |                         |                       |
|-------------------------|-----------------------|
| Analogue Computers      | Servo Mechanisms      |
| Radar                   | Electronic Circuits   |
| Communication Equipment | Aircraft Controls     |
| Hydraulics              | Instrumentation       |
| Electronic Packaging    | Printed Circuits      |
| Pulse Transformers      | Fractional H P Motors |
| Vacuum Tube Techniques  |                       |

Submit Résumé To  
Employment Office



**SPERRY  
GYROSCOPE CO.**  
DIVISION OF THE SPERRY CORP.  
GREAT NECK, L.I., NEW YORK

## NATIONAL UNION RESEARCH DIVISION

The Research Laboratories of one of the nation's larger electron tube manufacturers have vacancies for electronic engineers and engineering physicists qualified in the following fields:

- Vacuum tube development
- Electronic circuit design
- Electronic equipment

This organization can offer excellent prospects for security and personal advancement due to our continued growth. Our location is in the New York metropolitan area.

Whether you have a background of electron tube or circuit design, or are a recent graduate and interested in our field, we would like to hear from you. Send your résumé to:

Personnel Department  
NATIONAL UNION  
RESEARCH DIVISION

350 Scotland Rd. Orange, N.J.

## ENGINEERS

Work in Challenging Design and Development Fields Combining the Benefits of Essential Work with Security and Rapid Professional Advancement. Enjoy, among other Benefits:

- Salaries among the highest in industry . . . plus overtime and out-of-plant bonuses
- Cost of living benefits
- Liberal pension plan
- Company paid Blue Cross
- Company life, health & accident insurance
- Periodic merit reviews and merit increases

IMMEDIATE OPENINGS EXIST FOR MEN  
EXPERIENCED IN THE FIELDS OF:

- GYROSCOPICS
- ANALOG COMPUTERS
- FIRE CONTROL SYSTEMS
- SERVO MECHANISMS
- INSTRUMENT DESIGN
- CONTROL CIRCUITS

Reply by sending complete  
résumé to

TECHNICAL PERSONNEL  
DEPARTMENT

**ARMA CORP.**

254 36th St.  
Brooklyn 32, N.Y.



(Continued on page 158A)

### ELECTRICAL ENGINEERS

Electrical engineers with electronics training and experience for positions in the production, engineering, administration, and research departments of an expanding nuclear energy corporation. Send resume to: Industrial Nucleonics Corporation, 1205 Chesapeake Ave., Columbus 12, Ohio.

### SENIOR ENGINEERS

Senior systems engineers to set up and analyze complete weapons systems operations. Requirements: good mathematics background; familiarity with fire control equipments, including mechanical and electronic computers. Excellent opportunity at project engineer level. American Power Jet Co., Montclair, New Jersey.

### ENGINEERS

Positions are open in this securely established engineering and manufacturing organization as follows: PRODUCTION ENGINEERS; experienced in vacuum tube manufacture and familiar with microwave tubes and devices. TECHNICIANS: good electronic background in either tube products or research and development work. TUBE PRODUCTION MECHANICS: experienced in machine and equipment used in vacuum tube manufacture, and can operate and maintain them. TECHNICAL WRITERS: E.E. degree or electronic background and at least 1 year's experience planning and writing government specifications. Write Varian Associates, 990 Varian St., San Carlos, Calif. c/o Personnel Director.

## ELECTRONIC ENGINEERS

Outstanding opportunities to do advanced research on tubes and circuitry for peacetime and military applications of nuclear energy. Small research groups headed by specialists allow full development of creative ability.

Permanent positions are now available for senior engineers of proven accomplishment and for juniors with outstanding records.

Send complete résumé with salary requirements to:

Director of Personnel

**ANTON ELECTRONIC  
LABORATORIES, INC.**

1226 Flushing Avenue  
Brooklyn 37, New York

Interview appointments may be  
arranged at Booth 390, IRE Show

## ELECTRONIC ENGINEERS

### WHO WE ARE:

As a result of our recent affiliation with the Westinghouse Airbrake Co., we are entering a new and accelerated expansion program directed toward permanent growth in the industrial electronics field.

### WHAT WE OFFER:

To qualified, competent engineers, we offer truly permanent positions at salaries that rank among the highest in the industry. Additional compensation is paid for the extended work week.

### WHERE WE ARE:

We are located just outside Washington, D.C.—away from the hustle and bustle, yet close enough for you to enjoy all the advantages the nation's capital offers. Suburban housing in northern Virginia is available only a few minutes away from where we are located.

### HERE'S ALL YOU DO:

If you have experience in any of the fields listed below, you owe it to yourself to investigate career opportunities here. Of course, all replies will be strictly confidential.

- Computers
- Radar Beacons
- Telemetering
- Sub-Miniaturization
- Microwave Receivers
- Microwave Transmitters
- Millimicrosecond Pulse Circuits
- Research in Underwater Sound Systems

Send resumes to:

PERSONNEL DIRECTOR

**MELPAR, INC.**

452 SWANN AVE.  
ALEXANDRIA, VA.

# ENGINEERS

Insure your future in an expanding, progressive organization in the field of industrial applications of nuclear energy.

Responsible positions are available for:

## SALES ENGINEERS and PROJECT ELECTRONIC ENGINEERS

in

- RESEARCH
- DEVELOPMENT
- PRODUCT DESIGN
- PROJECT ADMINISTRATION

Engineers attending the IRE convention are requested to contact H. R. CHOPE at the Waldorf-Astoria. All qualified applicants are invited to write to

**INDUSTRIAL NUCLEONICS CORP.**  
1205 Chesapeake — Columbus, Ohio

## OPPORTUNITIES FOR EXPERIENCED

### ELECTRON TUBE ENGINEERS

RAYTHEON MFG. COMPANY  
SPECIAL TUBE SECTION

JOIN THIS ESTABLISHED ORGANIZATION AND BECOME A PART OF THEIR LONG RANGE EXPANSION PROGRAM. PLANT LOCATED IN RESIDENTIAL SUBURB OF BOSTON, THE EDUCATIONAL AND INDUSTRIAL HEART OF NEW ENGLAND.

- EXCELLENT OPPORTUNITIES TO IMPROVE FORMAL EDUCATION
- PERIODIC SALARY AND PROMOTION REVIEW
- HOSPITALIZATION & MEDICAL INSURANCE
- RETIREMENT PROGRAM
- EXCELLENT LIVING CONDITIONS
- SALARIES COMMENSURATE WITH ABILITY

#### MINIMUM REQUIREMENTS:

1. At least two years' experience or equivalent, in electron tube manufacture, design, research or development.
2. Outstanding record of achievement in this field.

If interested, send complete resume, including salary expected, to:

Mr. G. Lewis, Personnel Mgr.

**RAYTHEON MFG. COMPANY**  
RECEIVING TUBE DIVISION  
55 CHAPEL STREET  
NEWTON 58, MASS.



## Positions Wanted By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The Institute publishes free of charge notices of positions wanted by I.R.E. members who are now in the Service or have received an honorable discharge. Such notices should not have more than five lines. They may be inserted only after a lapse of one month or more following a previous insertion and the maximum number of insertions is three per year. The Institute necessarily reserves the right to decline any announcement without assignment of reason.

#### PHYSICIST

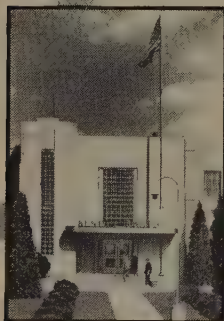
B.S. and M.S. in Physics. Age 28. 3 years' experience in teaching, 1 year in research. Desires research position in Queens or Long Island, N.Y. Write Box 543 W.

#### ENGINEER

B.E.E. large mid-western university. 3 years design and development of automobile broadcast receivers and some mobile communications equipment. Desires position in design and development requiring some administrative ability. Midwest Michigan preferred. Box 545 W.

(Continued on page 162A)

## MAKE THIS YOUR HOME FOR IMPORTANT WORK UNDER IDEAL CONDITIONS



- TV RECEIVER DESIGN ENGINEERS
- ELECTRONICS ENGINEERS
- FIELD ENGINEERS
- TEST & INSPECTION ENGINEERS
- LAB. TECHNICIANS

**NEEDED TO WORK ON:** Radar, G.C.A., Mobile Radio, Auto Radio, Airborne Communication & Navigation Equipment, Television, Antennas, Microwave Equipment, Servo Mechanisms and Guided Missiles.

**YOU BENEFIT AT BENDIX RADIO:**  
from high wages, a modern, air-conditioned plant, paid vacations and holidays, group insurance and a good chance for advancement.

Housing immediately available in the beautiful suburban and country areas that surround the Bendix Radio plant.

Write, Wire or phone  
MR. E. O. COLE, DEPT. M

**Bendix Radio**

DIVISION OF BENDIX AVIATION CORPORATION  
BALTIMORE-4, MD. Phone: TOWSON 2200

*Makers of the World's Finest  
Electronic Equipment*

## STAVID ENGINEERING, INC.

has openings for  
Graduate

### ELECTRONIC ENGINEERS MECHANICAL ENGINEERS

Experience in Design and Development of Radar and Sonar necessary.

Broad knowledge of Search and Fire Control Systems; Servo Mechanisms, Special Weapons, Microwave, Antenna and Antenna Mounts, etc.

Mechanical Engineer should have experience in packaging of Electronic Equipment to Gov't specifications including design of complex cabinets, shock mount and sway brace structures, Servo Mechanisms.

Positions are available in Field Service and Technical Writing.

Liberal personnel benefits including life, sickness and accident insurance, and a worthwhile pension system. Paid holidays and vacations.

Personnel Office  
312 Park Ave.  
Plainfield, N.J.  
Telephone  
Dunellen 2-1400

# ENGINEERS PHYSICISTS

A major expansion of THE JACOBS INSTRUMENT COMPANY has made available a number of positions for men qualified to take responsibility as Section Heads. A minimum of five years of experience, plus an outstanding record of achievement, is required. Experience should be in high frequency circuit design, systems studies, aircraft instruments, aerodynamics, servomechanisms, gyroscopes, optical instruments, missile guidance, fire control, digital or analog computers, or related fields.

These positions offer many unusual attractions including high salary, unusual opportunity in military and peacetime fields, security, employee benefits, and pleasant working conditions.

Qualified individuals interested in advancing themselves now should not overlook these opportunities.

**JACOBS**  
INSTRUMENT CO.

Bethesda, Maryland

# ELECTRONIC ENGINEERS

## AT DU MONT TELEVISION

Senior, Intermediate, and Junior for  
Interesting Career Opportunities in  
Design, Development, and Research

Ultra-High Frequency work, Radar systems, transmitting equipment, electronic instruments, and Cathode-ray tubes. Openings also for men experienced in pulsing, sweep, sync, multi-vibrator, Video Circuits, RF circuits, and IF systems.

## DU MONT

*Pioneer in Television and Electronics*

offers to qualified men high starting salaries, defense and peace-time job permanency, excellent advancement possibilities, regular merit reviews, and interesting work assignments.

Moving costs may be assumed by the Company for successful applicants. If possible, interviews will be arranged in your city.

Send complete information to

**ALLEN B. DU MONT LABORATORIES, Inc**  
Mr. George Kaye, Dept. IR-3  
35 Market Street  
East Paterson, New Jersey



# ENGINEERS

Special opportunities for YOU in

# SAN DIEGO

that sunshiny, smog-free city on the

# coast of CALIFORNIA

Convair (Consolidated Vultee Aircraft Corporation) is now accepting applications for these following positions in its modern, progressive Engineering Department.



## Microwave Engineers

## Servomechanism Engineers

## Electronics System Engineers

## Electronic Circuit Designers

Unusual opportunities for those experienced in the design and analysis of Radar and Missile Guidance Systems.



Be sure to see Convair's Booth 500 at the I.R.E. Convention, March 3 thru 6.

## WORKING FACTS: You get two holidays a week at

Convair — overtime accomplished in 5-day week. Attractive salary ranges. An "engineers" engineering department... with stimulating, competent associates... and interesting, challenging, essential, long-range projects of a wide variety including — commercial aircraft, military aircraft, missiles, engineering research and electronic development. Excellent patent royalty arrangements. Top-notch retirement plan — better than-average life and health insurance. Complete progress-salary review for each person twice yearly. Opportunity for continuing engineering education.

**LIVING FACTS:** San Diego, with its wonderful residential areas, offers you and your family incomparable living. Ideal climate — cool, clean, dry. Mountains, desert, Mexico, Hollywood, Los Angeles, Pacific Ocean, beaches and bay — only hours or minutes away. It offers you a new way of Life... pleasant, refreshing, happy.

If you qualify, you will receive generous travel allowances.  
**SEND COUPON** for free booklets and complete information.

## THANK YOU

Mr. H. T. Brooks, Engineering Department 800

Convair, 3302 Pacific Hiway, San Diego, California

Please send me **FREE** booklets describing the Convair Opportunity for me and my Convair Application Form.

My name \_\_\_\_\_

Occupation \_\_\_\_\_

Address \_\_\_\_\_

City \_\_\_\_\_ State \_\_\_\_\_

# ENGINEERS

wanted at once  
for  
**LONG-RANGE MILITARY  
AIRCRAFT PROGRAM**  
by  
**North American Aviation,  
Inc.**  
**Los Angeles, California  
Columbus, Ohio**

Unusual opportunities for Aero-  
dynamicists, Stress Engineers,  
Aircraft Designers and Drafts-  
men, and specialists in all phases  
of aircraft engineering. Engineer-  
ing skills other than aircraft may  
be adaptable through paid train-  
ing program. Also openings for  
**Recent Engineering College  
and Technological Graduates**

Long-range military program of-  
fers fine chance for establishing  
career in aircraft while aiding de-  
fense effort. Transportation and  
established training time paid.  
Salaries commensurate with ex-  
perience and ability.

Please include summary of  
education and experience in  
reply to:

Engineering Personnel Office

SECTION P-8

**NORTH AMERICAN  
AVIATION, INC.**

Los Angeles International  
Airport

Los Angeles 45, Calif.

or

Columbus 16, Ohio

## Positions Wanted

(Continued from page 160A)

### ELECTRONIC ENGINEER

B.S.E.E. 1948 and M.S.E.E. 1952. 2 years  
Navy as electronic technician; 3 years develop-  
ment and operation experience on radar beacon  
system for guided missiles. Prefer development,  
design, or test work in southwest. Available Feb-  
ruary. Age 27, married. Member of Sigma Tau  
and Eta Kappa Nu. Box 549 W.

### TELEVISION PROJECT ENGINEER

Air Force officer engaged in military TV de-  
velopment expects release shortly. 3 years TV  
development with leading broadcaster; thorough  
understanding of terminal and special equipment.  
Not interested in receivers or production. Cre-

dentials and resume on request. Minimum salary  
\$7000. Box 550 W.

### ELECTRONIC ENGINEER

B.S.E.E. University of Michigan. Navy ETM.  
4 years post-war experience in design and de-  
velopment for production of electronic compo-  
nents and equipment. Desires position in design,  
development, production or administrative engi-  
neering. Prefer New York area. Box 551 W.

### INSTRUCTOR

Licensed instructor of Radio, FM and TV.  
Can teach mathematics, theory or shop practice.  
Will consider school within commuting distance  
of Poughkeepsie, N.Y. Box 552 W.

(Continued on page 163A)

# ENGINEERS . . .

## ELECTRONIC MECHANICAL

## Interesting and Important Positions Are Offered

in all levels of:

RESEARCH . . . DEVELOPMENT

DESIGN . . . TEST

All phases of work in the **COMPUTER FIELD**, such as:

Systems

New Components

Input-Output Devices

Product Design

New Product Studies

New Business Methods

Computer Test and

Maintenance

Experience in Computer, Television, Radar, or Guided Missile Field is  
desirable, but not necessary.

We invite you to Write . . . Phone . . . Apply

### ECKERT-MAUCHLY COMPUTER CORP.

(Division of REMINGTON RAND Inc.)

2300 Allegheny Ave.

Philadelphia 29, Pa.

Telephone BALdwin 3-7300

## Loud Speaker Engineer

Wanted with several years development and acoustic  
measurement experience. Position now open with large  
Eastern manufacturer. All replies will be held confidential.

**Box 685**

The Institute of Radio Engineers  
1 East 79th St., New York 21, N.Y.

## Positions Wanted

(Continued from page 162A)

### ELECTRONIC ENGINEER

B.E.E. Cooper Union. 5 years research and design on electronic organs. 3 years Army radio technician. Industrial control design experience in electronic packaging. Married, age 31, 2 children. Prefer New York area. Box 553 W.

### ENGINEER

B.S.E.E., M.S. medical science, Navy ETM, 4 years' experience in electronic medical instrumentation. Desires position in instrumentation. Box 557 W.

### ELECTRONIC ENGINEER

B.E.E. 1949, Cooper Union. Experience in design and development of test equipment, TV and radar broadband amplifiers. Other experience. Married, age 26. Desires position in New York area. Box 558 W.

**27,500 Radio Engineers**  
will visit the Radio Engineering Show at Grand Central Palace, New York City, March 3-6.

## MECHANICAL ENGINEER SENIOR

FOR

SYLVANIA'S

LONG ISLAND RESEARCH  
& DEVELOPMENT  
LABORATORIES

To work on mechanical design and development of vacuum tubes, electronic devices, experimental tools, dies, and laboratory equipment.

BS in ME and minimum of 5 years experience in electro-mechanical field essential.

Please send complete resume to:  
MANAGER OF PERSONNEL

DEPT. ME-1

SYLVANIA  
ELECTRIC PRODUCTS, INC.  
40-22 Lawrence St., Flushing, N.Y.

## ELECTRONIC ENGINEERS

### What More Could You Want?

Than a responsible position with a small personalized firm, at a good salary, in a nice location—*plus* opportunity to advance.

**THE POSITION:** We have openings for Junior, Project, and Senior Engineers. Whichever it is, you will be given responsible work to do *immediately*. No waiting for the red tape to unravel.

**THE FIRM:** The New London Instrument Company is a small, friendly firm, owned and operated by engineers. We make advanced electronic instruments and equipment. With us, you will be an individual—not a number on a punch card.

**THE SALARY:** Commensurate with education and experience.

**THE LOCATION:** New London, Connecticut is a summer resort right on Long Island Sound. Fishing, swimming, and living are all good. 120 miles from New York City, 100 from Boston.

**OPPORTUNITY:** We're a growing concern that stresses and recognizes technical ability.

*Inquiries will be handled confidentially*

WRITE TO:

**New London Instrument**  
NEW LONDON, CONNECTICUT  
*Company*

DESIGNERS and MANUFACTURERS of

Signal Generators  
Frequency Meters

Commercial Communication  
Receivers

## ELECTRONIC ENGINEERS

**Sperry**

Wide range of experience including design of wide band receivers, radar display systems, analogue computers, servo systems & CR oscillographs . . . thorough knowledge of RF circuits, wave shaping, pulse forming, triggers & gates (microwave techniques unnecessary).

### A FEW KEY POSITIONS . . .

Opening of our own manufacturing facilities creates permanent positions in research and development of vital, long-range products.

### CONSIDER THESE ADVANTAGES . . .

- . . . Gracious country living, free from big-city pressures, provides a relaxing atmosphere in which you can do your best work . . . yet with in easy reach of the cultural advantages of New York City.
- . . . Association with an established yet growing organization with few competitors in the field, where your merit and ability are given full consideration.
- . . . Unusual company-paid benefits . . . 40-hour week with considerable premium overtime . . . moving expenses paid.

TAKE ADVANTAGE OF THIS OPPORTUNITY NOW! Address all inquiries to J. H. McCann

**SPERRY PRODUCTS, INC.**

DANBURY, CONNECTICUT

# SYLVANIA'S

Central Engineering Laboratories

in

Bayside, Flushing, Kew Gardens, Mineola, L.I.

*Offer to Qualified*

## ENGINEERS • PHYSICISTS • MATHEMATICIANS •

- . . . Career Opportunities in Research and Development
- . . . A Chance to Grow and Contribute Professionally
- . . . Invaluable Experience in Dynamic New Fields
- . . . Opportunity for Graduate Study

Opportunity is a key word at Sylvania. Expanding programs are underway in important new fields of long range interest in the Electronic and Physical Sciences.

Please Address Inquiries to:

Manager of Personnel, Dept. G-1

**SYLVANIA ELECTRIC PRODUCTS, INC.**

40-22 Lawrence Street Flushing, New York



## WANTED

Project Engineers, Design Engineers, and Laboratory Technicians for large manufacturer of electronic components.

Engineers having experience with connectors of all types preferred.

Good opportunity for advancement with a well established firm.

CINCH MFG. CORP.

1026 S. Homan Avenue  
Chicago 24, Illinois



## Field Test Positions in CALIFORNIA on Guided Missiles ENGINEERS

Electronic  
Aeronautical  
Servomechanical  
Telemetering  
Mechanical

## TECHNICIANS

Electronic  
Mechanical

**APPLY NOW** for this long-term  
testing program to:

FIELD TEST DIRECTOR  
BELL AIRCRAFT CORPORATION  
NAVAL AIR MISSILE TEST CENTER  
POINT MUGU  
PORT HUENEME, CALIFORNIA

**BELL Aircraft CORPORATION**

## ENGINEERS SCIENTISTS TECHNICIANS

ARMOUR RESEARCH FOUNDATION OF  
ILLINOIS INSTITUTE OF TECHNOLOGY

**URGENTLY NEEDS TOP LEVEL  
ENGINEERS AND SCIENTISTS  
FOR ITS EXPANDED RE-  
SEARCH AND DEVELOPMENT  
ACTIVITIES.**

Electronic engineers with experience or advanced training in antennas, microwave, television or general communications work.

Electronic engineer for general circuit work on instrumentation for medical, meteorological and industrial applications.

Engineer with training and experience in servomechanisms, including systems analysis, network synthesis and instrumentation for flight simulators, fire control systems and industrial control applications.

Engineer with experience in electronics and/or electromechanical design for research and development in the magnetic recording field.

Engineer with experience in development of electromechanical or electromagnetic devices such as small motors, relays, and transformers.

Engineer or physicist interested in precision electrical measurements, electrical insulation or arc interruption problems. Prefer man with advanced training or equivalent experience.

Electronics or electrical engineering technicians for work as laboratory assistants in development of prototype models of equipment. Prefer men with trade school training or equivalent experience.

**ARMOUR RESEARCH FOUNDATION  
SERVES INDUSTRY AND  
GOVERNMENT IN RESEARCH  
AND DEVELOPMENT COVER-  
ING THE FIELDS OF SCIENCE  
AND ENGINEERING. WORK IS  
STIMULATING AND OFFERS  
DIVERSIFIED ACTIVITY AS  
WELL AS WIDE CONTACT IN  
PROFESSION AND INDUSTRY.  
POSITIONS DESCRIBED OF-  
FER OPPORTUNITIES FOR  
PROJECT LEADERSHIP IN IM-  
PORTANT NEW FIELDS OF  
RESEARCH. SALARIES OPEN  
FOR DISCUSSION AND WILL  
BE COMMENSURATE WITH  
TOP LEVEL CAPABILITIES RE-  
QUIRED FOR THESE POSI-  
TIONS.**

Write for descriptive brochure of the  
Foundation. Interviews will be arranged.  
Address inquiries to:

**ASSISTANT DIRECTOR FOR PERSONNEL  
ARMOUR RESEARCH FOUNDATION OF  
ILLINOIS INSTITUTE OF TECHNOLOGY**

35 West 33rd Street  
Chicago 16, Illinois

## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation. (Continued from page 153A)

### Resin Core Solder

A new and highly active resin flux, known as "44" resin, has been announced by Kester Solder Co., 4201 Wrightwood Ave., Chicago 39, Ill.



According to the manufacturer, "44" resin surpasses any resin now known to the solder industry in speed of action for fast soldering. The solder melts, "wets" the metal, and flows or spreads all in one instantaneous action with a speed that makes it impossible to distinguish the separate actions.

Kester "44" resin is noncorrosive and electrically nonconductive. It conforms (Continued on page 170A)

## ELECTRICAL ENGINEER OR PHYSICIST

UNUSUALLY INTERESTING  
OPENING AS PATENT ENGINEER

Requires experience in electronic circuits, with aptitude for writing and library research. Must be interested in servomechanisms, data transmission, and the magnetic amplifier art. Ability to investigate and analyze research results for features of patentable novelty required. Duties involve liaison between engineering laboratories and patent department. Starting salary and opportunities commensurate with experience, education, and ability. Acquaintance with patent law not necessary.

APPLY OR SUBMIT RESUME  
TO EMPLOYMENT OFFICE

**SPERRY  
GYROSCOPE CO.**

DIVISION OF THE SPERRY CORP.  
GREAT NECK, L.I., NEW YORK

## FOR YOUR PANEL

A NOVEL and UNIQUE CIRCUIT INDICATOR

**DIALCO**

DESIGNED FOR NE-51 NEON LAMP

For 110 or 220 volt circuits

The required resistor is  
an integral part of this assembly  
—"built-in."

**RUGGED • DEPENDABLE  
LOW IN COST**



PATENTED: No. 2,421,321  
Cat. No. 521308-997



## WILL YOU TRY A SAMPLE?

Write on your company letterhead. We will act at once.  
No charge, of course.

**SEND FOR THE 192 PAGE HANDBOOK OF PILOT LIGHTS**

Among our thousands of Pilot Light Assemblies there is one which will fit your special conditions. Many are especially made and approved for military use. We pride ourselves on prompt deliveries—any quantity.

**ASK FOR OUR APPLICATION ENGINEERING SERVICE**

Foremost Manufacturer of Pilot Lights

**The DIAL LIGHT COMPANY of AMERICA**

900 BROADWAY, NEW YORK 3, N. Y.

SPRING 7-1300

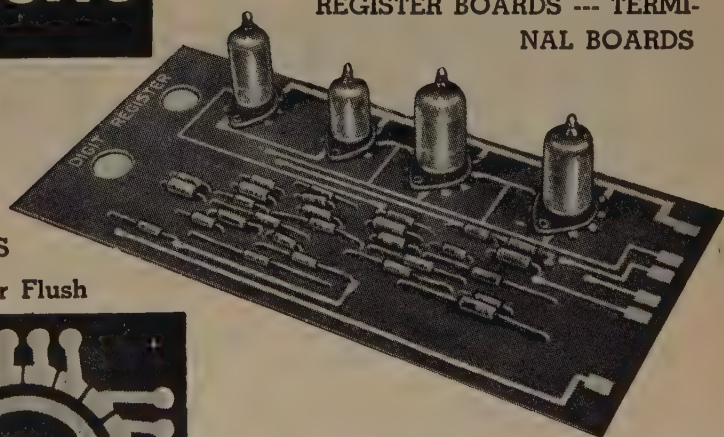
## PRINTED CIRCUITS

SWITCH  
PLATE  
CONTACTS

Raised or Flush



CHASSIS ASSEMBLIES --- SWITCH-  
ING PLATES --- SUB-ASSEM-  
BLIES --- COMMUTATORS ---  
REGISTER BOARDS --- TERMI-  
NAL BOARDS



CONDUCTIVE MATERIALS: Copper, Silver, Steel, Bronze, Brass, Nickel, Aluminum.  
PLATING: Copper, Silver, Nickel, Aluminum, Gold, Silver, Chrome.  
INSULATING BASES: Phenolic, Melamine, Silicone, Polyester, Polystyrene, Polyethylene, Lucite, etc.; Ceramics.  
OPERATIONS PERFORMED: Die Stamping, Intricate Piercing, Plating, Injection Molding, Machining, Soldering, Assembly, Research.

For additional information, write to  
PRINTED CIRCUIT DEPT.

**Emeloid**  
1239 Central Ave.,  
Hillside 5, N. J.

Supplier of PLASTIC PRODUCTS to  
The Radio and Electronic fields since 1919

ELIZABETH 2-1944 - 1945 - 1946  
N. Y. C., RECTOR 2-8554 - 8555

See us at Emeloid's booth No. 472

(Continued from page 169A)

with Specification MIL-S-6872 (AN-S-62) (a 3-day humidity test at 100°F.), and the U. S. Air Force Specification 0.41065-B-Method 31 (a 14-day humidity test at 160°F.) and also with Federal Specification QQ-S-571b.

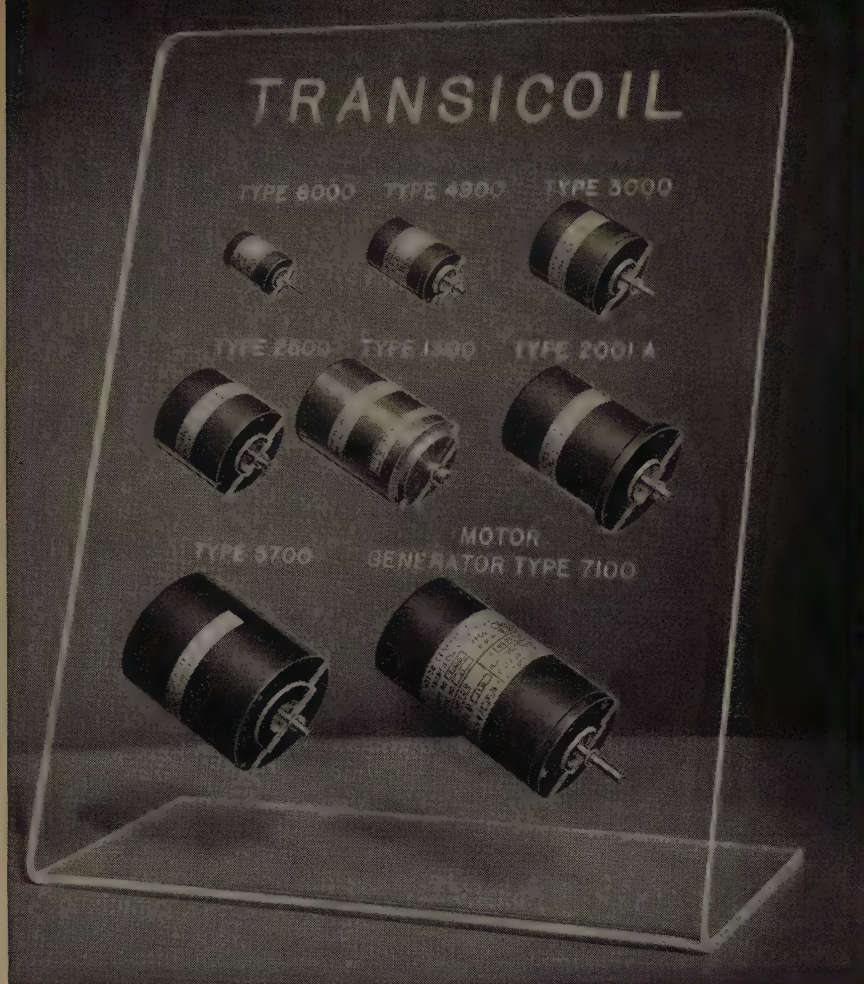
For complete information write for Bulletin No. 444. Samples and engineering or technical assistance are also available upon request.

### Oil-Immersed Rectifier Tubes

Westinghouse Electric Corp., 306 Fourth Ave., Pittsburgh 30, Pa., has two new, high-voltage, oil-immersed rectifier tubes which are quite compact and both of which are two-element vacuum tubes. One is a 40-kv peak inverse-voltage tube, capable of 150-ma average and 900-ma peak current, and is about the size of a tennis ball. Oil immersion, is desirable not only to keep the size down, but also to maintain the voltage breakdown strength and to reduce the effect of rapid temperature and pressure changes when the rectifier is carried aloft as part of a radar set. The second rectifier, of similar construction, provides 125-kv (peak inverse) for heavy-dust precipitation equipment. It is rated at 300-ma average, and 1-ampere peak, but is only 11½ inches long, and with a tube portion diameter of only 4 inches.

Its size is about one tenth that of the air-cooled variety.

(Continued on page 173A)



# TRANSICOIL

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## ELECTRONIC ENGINEERS

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Tung-Sol Electric Inc., Radio and Television tube manufacturers, is now interviewing qualified engineers for immediate job openings at excellent salaries with fine opportunities for advancement.

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Write or apply in person to

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**TUNG-SOL ELECTRIC INC.**

200 Bloomfield Ave., Bloomfield, N.J.

# News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 170A)

## Binding Post

A new improved binding post, Model K952, is available from Kings Electronics Co., Inc., 40 Marbledale Rd. Tuckahoe, N. Y. It incorporates the quick disconnect principal with a spring loaded action and stainless steel locking jaws.



Teflon insulation throughout provides low dielectric loss, no moisture absorbance, no carbon tracking, and the maintenance of mechanical properties in the binding post. The temperature application range is from 67° to +149° F. Complete moisture sealing on the chassis itself is effected by a special teflon and rubber combination. Color-coded removable rubber caps can be provided for identification and personnel protection. The unit is silver plated right to the base, which is a chessman type for easy soldering. The design of the binding post is such that it can be operated with ease by a person wearing an arctic glove.

## DC Breaker Amplifier

Liston-Becker Instrument Co., 20 Beckley Ave., Stamford, Conn., announces a new, improved, ultra-sensitive dc breaker amplifier, Model 14, which replaces the former Model 10. This dc amplifier, the manufacturer claims, has the lowest noise level and the highest zero stability of any dc amplifier commercially available.



The Model 14 can be furnished for operation with input circuits between 5

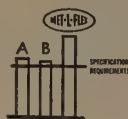
(Continued on page 174A)

# This is about "Shock Mounts" (Vibration Mounts for Airborne Equipment)



With 25% to 50% of the cost of a modern military airplane in electronic equipment, the once overlooked and often forgotten shock mounts have now come into a position of key importance. Their cost in relation to the equipment is insignificant; but their ability to protect valuable equipment should receive most careful evaluation by every design engineer. Only objective comparison will show the great difference in mounts. Most mounts are alike in general appearance.

Fundamentally, the fact that a mount complies with a given specification is the beginning of good design — not the end. Today, mounts which deliver more than the specification requirements; "plus" features — features of design and performance — pay off in maximum equipment protection through the widest range of operating conditions.



Robinson mounts basically have one important exclusive advantage: a superior load carrying cushioning element; MET-L-FLEX. This all-steel resilient material is knitted from stainless steel wire, compacted and compressed under an exclusive process. The elastic element thus formed is, in effect, a multiplicity of interlocked springs with built-in high damping, giving "Sea level performance at any altitude." This MET-L-FLEX cushion is then housed in a protective stainless steel spring, precision formed and with ground ends, which carries about 15% of the total load and holds the MET-L-FLEX in perfect alignment.

This exclusive design provides non-linear load deflection characteristics, and permits Robinson mounts to be overloaded or underloaded as much as 50% of their mean rated capacities.



Auxiliary MET-L-FLEX limiters, built into each mount, afford additional equipment protection against overloads due to combat maneuvers or landing impacts. The all-metal construction and the simple, rugged design provide three other important advantages: MET-L-FLEX mounts have a negligible drift rate; they are unaffected by extremes of temperature or other environmental conditions; and they are amazingly long-lived.

Weight comparisons are interesting, too! Robinson unit mounts, with their advanced design, weigh 50% less than some competitive mounts, yet have ultimate strength far exceeding specification requirements. Another reason why you should compare before you specify!



Leadership doesn't happen overnight. Year after year Robinson has pioneered advanced designs for airborne applications. MET-L-FLEX unit mounts and mounting systems were the first successful all-metal airborne mounts, and Robinson has produced more all-metal mounts and mounting systems than all other manufacturers combined.

Production facilities have been expanded and have kept pace with increased demand.

Robinson know-how is yours in every MET-L-FLEX system. Robinson engineering and research are ready to help you solve your vibration control problems.

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*Vibration Control Engineers*



## NEY #90 ALLOY

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NEY #90 Alloy, overcomes many of the disadvantages of coin silver when used in slip ring and commutator bar applications. Actually a modification of coin silver, NEY #90 is subjected to a carefully controlled processing that produces a uniform hardness of 120-130 Brinell which has been found best for slip ring type applications. Since performance is also markedly influenced by surface condition, especially when brush pressure must be low, NEY #90 Alloy rings are given a specially developed finish that greatly reduces wear and electrical noise. NEY #90 Alloy is available in seamless tubing in all sizes up to 4" O. D., also in the form of plate, rod, wire and fabricated parts.

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## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 173A)

and 100,000 ohms. It has a noise level which closely approaches the limits imposed by thermal agitation, and has a zero stability of 0.005 microvolt per day. This amplifier can be employed in circuits which formerly used high-sensitive suspension galvanometers.

This amplifier has found use in both research and industry in such diverse fields as optical pyrometry, precision temperature measurements, calorimetry, high-sensitive photometry, spectroscopy, chemotherapy, seismology, meteorology, petroleum exploration, and in the physiological applications of measuring nerve voltages, blood-flow meters, and oximeters.

The price is \$665.00.

## Converters for Mobile Operation

A new series of converters, to be used for mobile reception on 10-, 20-, and 75-meter bands, has been announced by **Mallard Mfg. Co.**, 6025 N. Keystone Ave., Chicago 30, Ill.

Featuring nylon gear drive and slug-tuned coils, the new converters are said by the manufacturer to be exceptionally sensitive and to possess unusual stability under the adverse conditions of mobile operation.

The 10N, 20N and 75N converters provide single-band reception on the amateur bands indicated by the model numbers.



They utilize 6AB4 oscillators, which function efficiently even with low battery voltage common during sub-freezing temperature periods. The 10-20 converter provides reception on both 10 and 20 meter bands and is available with or without built-in noise limiter. Band switching is accomplished with a two-position sliding switch board that permits extremely short leads, thus assuring efficiency for two band operation.

## JAN Cross-Reference Guide

A JAN Cross-Reference Guide, showing joint Army-Navy components and their commercial equivalents, has been prepared for the benefit of buyers of electronic equipment by the **Hudson Radio**

(Continued on page 176A)

# The New

## Mandl's

### Television Servicing

gives you detailed, illustrated trouble-shooting procedures for every flaw or failure you're likely to encounter.

A COMPLETE MASTER INDEX and separate lists of trouble symptoms for each circuit defect make it easy to locate any particular trouble and the exact procedures for correcting it. Unusual, hard-to-find flaws as well as all common trouble are dealt with.

THE LATEST CIRCUITS are explained and illustrated, including servicing techniques for UHF and VHF.

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and these are only a few of the features that make this the most helpful, practical, and complete service manual yet to be published.

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by Noll & Mandl. A basic course on theory plus a complete handbook on all types of antennas and installation procedures.

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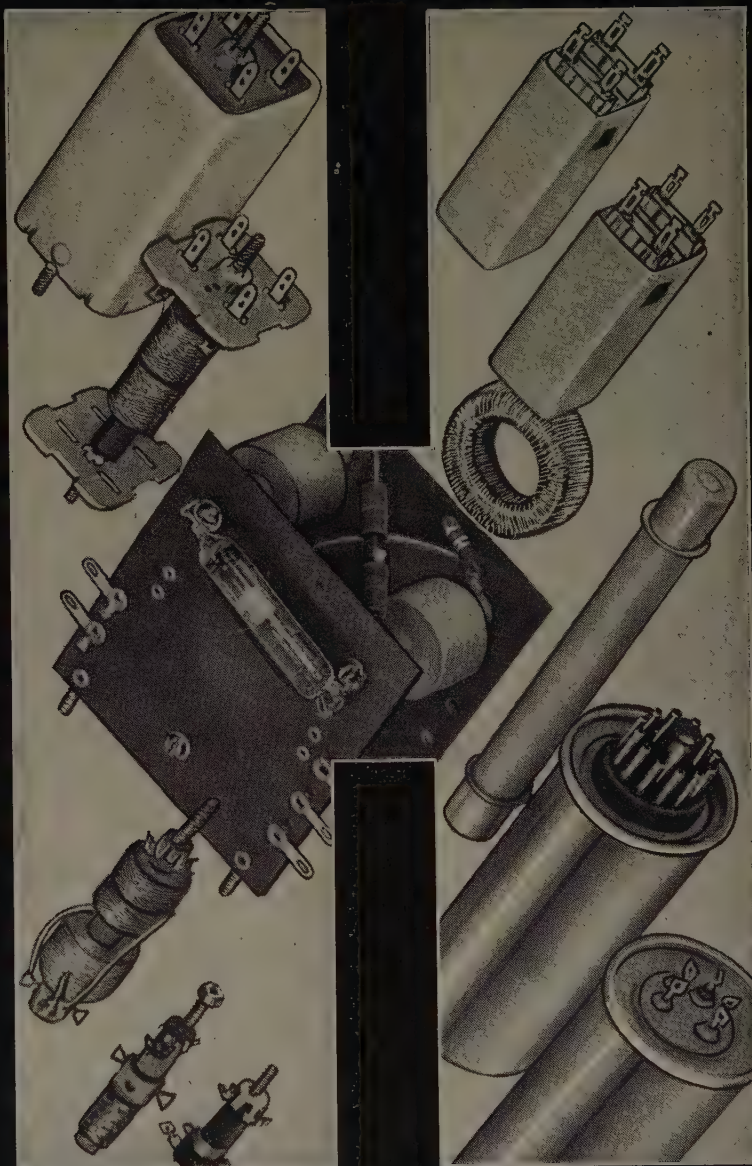
Radio Engineering Show - March 3-6,  
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## News—New Products

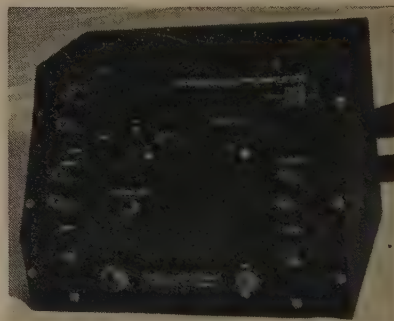
These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 174A)

and Television Corp., 48 W. 48 St., New York 19, N.Y. Listing thousands of items, it is expected to save purchasing agents and engineers endless hours of searching through individual catalogs for critically needed parts and supplies. The guide will be kept up-to-date by the publication of supplementary charts.

### Differential Preamplifier

Owen Laboratories, 412 Woodward Blvd., Pasadena 10, Calif., has a new Type 180 accessory amplifier to be used with any laboratory oscilloscope in the investigation of low-level, low-frequency signals. It provides either single-ended or differential amplification (that is, amplification of only the difference between voltages applied to the two input terminals, any component common to the two signals being balanced out internally). Output is single-ended only, and the voltage gain is 50.

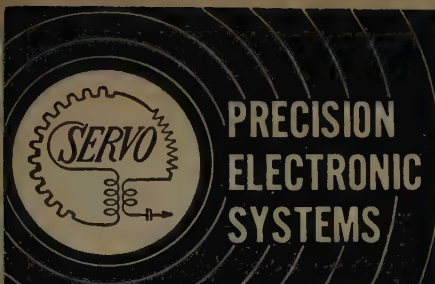


Type 180 has a low internal noise level, and therefore can be used ahead of high-gain oscilloscopes. Noise at the output is about one millivolt rms, most of which is line-frequency ripple. This is about 20 microvolts referred to the input.

The amplifier circuit is direct-coupled except for a one-microfarad capacitor in series with the output terminal. There is no drift of output level, yet the low-frequency response is adequate for almost any purpose, depending of course of the input resistance of the oscilloscope. When used with the Du Mont 304H, or similar dc scope having an input resistance of two megohms, the response to sine waves will be down 10 per cent at 0.1 cps, and the top of a rectangular pulse  $\frac{1}{2}$  second in duration will drop 10 per cent.

The gain is approximately 50 times, or 34 db. The high-frequency response is flat to beyond 20 kc. For a one-volt rms 500-cps signal, applied simultaneously to both input terminals, there will be about one millivolt output. This is an in-phase signal attenuation of 1,000:1, or 60 db. Input impedance is one megohm at either input; the output impedance is less than 1,000 ohms. The price of the amplifier \$125.

(Continued on page 178A)



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- Direction Finders  
Electronic Goniometer
- Signal Generators  
"Resonant" Control  
1 kc to 150 mc.
- Spectrum Generator  
Marker Pulses  
.5 to 50 mc.

### CONTROLS

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- "Servotherm"
- "Servo"  
Amplifiers
- Bolometer Electronics
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*for minimum size, maximum  
dependability, convenient  
rectangular shape*

**TYPE TC** — TEMPERATURE COMPENSATING CERAMIC PLATE CAPACITORS.

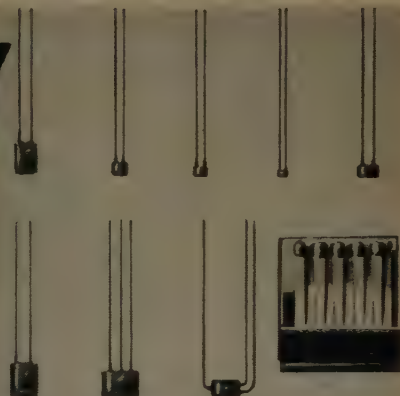
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Many standard types, including a great variety of temperature compensating ceramic capacitors, are available. Quotations on these or types will be supplied promptly.



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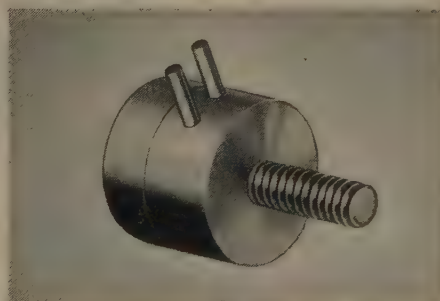
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*featuring—*

- HIGH SENSITIVITY
- GOOD STABILITY
- HIGH RESONANT FREQUENCY
- SMALL SIZE
- ABSOLUTE DEPENDABILITY



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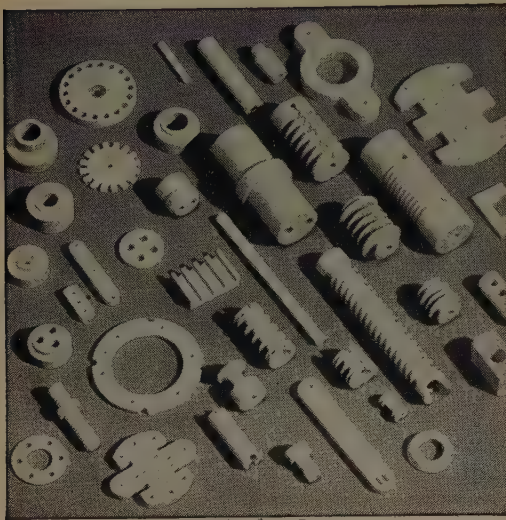


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- HYDROPHONES
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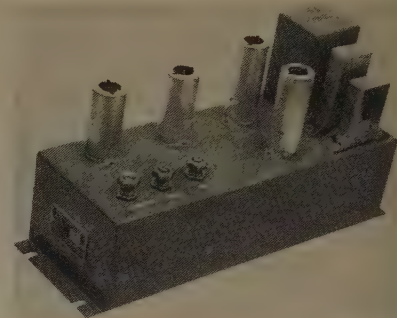
## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 176A)

### 400 cps Servo Amplifiers

Industrial Control Co., Wyandanch, L. I., N. Y., has developed the 421-A and 423-A universal, 400-cps servo amplifiers, designed to drive two-phase servo motors requiring 6 and 9 watts per phase, respectively. They feature independent screwdriver controls on damping, gain, and carrier phase, and therefore can be stocked for use in all servo loops requiring their respective servo motors.



Other characteristics are as follows: maximum gain, 1,000; phase adjustable thru 160 degrees; internal pickup below 2 millivolts; damping adjustable over wide range. Their plate and filament power can be furnished by any power supply with no regulation, filtering, or additional bias sources necessary. They will function with any carrier frequency data system, and yield servo loops of broad frequency transmission and low static and velocity errors.

These amplifiers, together with their 60-cps predecessor, the 410-B, advance the concept of "breadboard circuitry." By using these units, together with breadboard mechanical apparatus, a servo loop can be set up in the few hours required to design and construct an interconnecting harness.

### Ultra-Low Frequency Oscillator

Krohn-Hite Instrument Co., 580 Massachusetts Ave., Cambridge, Mass., announces a new ultra-low frequency oscillator, Model 400-A.



The Model 400-A ultra-low frequency oscillator provides simultaneously both

(Continued on page 179A)

## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 178A)

sine and square-wave voltages at any frequency between 0.009 and 1,100 cps. An RC bridge sine wave oscillator circuit is employed with special circuitry to eliminate tuning and switching transients. Other features are low hum and distortion, excellent amplitude constancy over the entire frequency range, a single scale logarithmic dial with a vernier tuning control, and low input power.

The 400-A is especially useful for the designing and testing of servomechanisms, for geophysical and seismological instruments and feed-back amplifiers, for vibration checks and medical research, and in conjunction with tuning and production controls. The square wave output is also useful for low frequency switching and triggering operations, and for frequency or transient response measurements.

The dimensions of the unit are 12×7×8 inches, and the price is \$350.00. A descriptive pamphlet is available on request.

### Nylon Plug Base

The new plug base, manufactured by Industrial Devices, Inc., Edgewater, N. J., is for capacitors of the Type CE50 Series, fitting a standard medium octal socket. It

(Continued on page 180A)

# CAPACITORS

## TO MEET MILITARY SPECIFICATIONS



- Oil-Impregnated
- Stabilized Halowax
- Molded paper
- Metal cased
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# A NEW SINGLE-SIDEBAND RECEIVER

Complete triple-diversity system in compact single-rack mounting for receiving all forms of double and single-sideband transmission . . . including reduced-carrier single-sideband operation . . . with exalted-carrier detection to eliminate distortion caused by selective fading.

For program, voice, tone-multiplex and twin-channel operation; optimum performance in rejecting interference; protected against jamming.

Diversity combining system automatically selects strongest signal and rejects weak signals, resulting in optimum signal-to-noise ratio at all times.

Employs standard communications receivers. Each receiver section has individual power supply and may be operated independently if desired.

Provides a receiver of peak performance for today's techniques as well as tomorrow's advanced requirements in single-sideband communications.

Substantially increases reliability of long-range radio circuits of governmental services, air lines, international press and broadcast facilities.



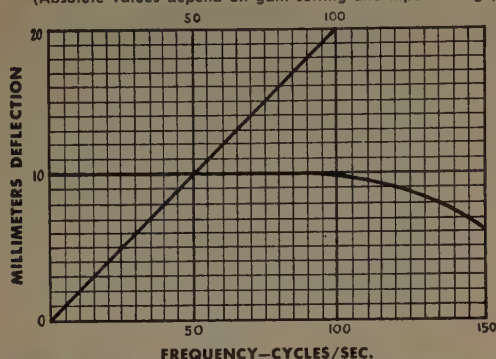
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## DIRECT RECORDING INSTRUMENTATION

% INPUT VOLTS FOR FULL SCALE DEFLECTION  
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## RECORDER AND AMPLIFIER COMBINATIONS

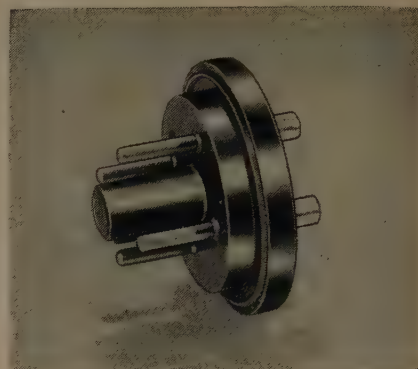
- 1, 2, 4, or 6 channel recorders driven by a selection of DC, high gain AC or combination AC/DC amplifiers
- Rack mounted, mobile units are available

## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 179A)

is suitable for use in capacitors made under JAN-C-62 specifications, and carries a manufacturer's designation of Model #1800.



Through the use of Nylon, important advantages have been achieved over ordinary phenolic bases. Most important is the toughness of this unit, which reduces breakage to a minimum while assembling to metal cans or other related parts. Because of the high strength of this material, it has been possible to hollow the unit to a great extent, thus making it lighter and saving material. The Nylon used on this base has a melting point in excess of 425° F, and has excellent electrical properties as well.

Slight resiliency of the material eliminates danger of base cutting cathode tabs, and also results in a better seal to the metal can. This same resiliency aids the fabricator by lessening the chances of the can rotating on the base either during or after the spinning process.

## Audio Oscillator

General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass., has developed a Type 1214-A Unit Oscillator, a simple two-frequency oscillator (400 and 1,000 cps) useful as a modulating source for high-frequency oscillators, such as the Types 1208-A and 1209-A, as well as a general-purpose laboratory source. The

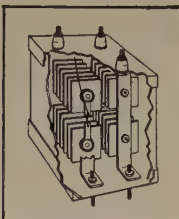


0.2-watt output, with less than 3 per cent distortion, is also adequate for bridge-measurement work and many other fixed-frequency applications.

(Continued on page 181A)



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hermetically sealed  
selenium rectifiers  
to your order...**



Cutaway view of typical internal mounting arrangement of a multiple stack, hermetically sealed rectifier assembly.

OF COURSE, this type of rectifier is usually for military and naval installations... and the occasional uses where the extra cost of sealing is justified by the extra results achieved.

For some time now we've produced oil filled, hermetically sealed rectifiers on order in a variety of ratings... so if you have an application in mind that calls for the utmost in protection against atmospheric conditions or unusual shock, send us your specifications. We'll gladly supply engineering data and quotations.

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AC INPUT	DC OUTPUT CURRENT
96V	1.6 amps
24V	0.9 amps
48V	0.25 amps
168V	0.3 amps

Regular SELETRON selenium rectifiers are the choice of an ever increasing number of manufacturers in diversified fields because they are so thoroughly dependable under all types of grueling conditions. They're available in the miniature sizes for radio, TV and other electronic circuits, all the way up to heavy duty power stacks used in industrial applications. Write us today for Bulletin No. 104-E-1

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# News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 180A)

Compact and inexpensive, Type 1214-A differs from other GR unit instruments in having its own power supply built in. This was done as an economy, because the iron-core tuning inductance could have an isolated output coupling coil thus allowing the Type 117N7-GT diode-pentode, used as voltage doubler, to work directly off the ac line.

For complete details see Page 5 of the October 1951, *General Radio Experimenter*, available on request.

## Octal Type 9-Pin Connector

A new octal type 9-pin connector, 209FEC, and plug, 109C, for use with TV color adapters, uhf converters, or wherever a rugged, small connector is needed, is announced by Alden Products Co., 117 N. Main St., Brockton 64, Mass.



The 209FEC, shown on the right, has long leakage paths giving excellent breakdown rating. Special "Top Connected" contacts use a minimum of critical material, yet they are designed for low resistance and long life.

Basic simplicity with no disks, wafers, drive pins, or rivets, is realized in the 209FEC.

There are no projecting solder terminals as the leads are attached directly to the contact. Each contact and lead has 100 per cent molded insulation around it, and each lead has its individual strain relief. The wire tip is crimped firmly, eliminating the danger of cold solder joints.

For additional information or price quotations call Nelson Hearn, Brockton 160.

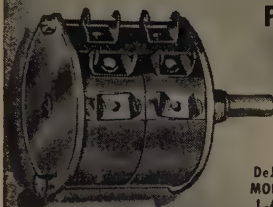
(Continued on page 183A)

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PRECISION  
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# DeJUR

PRECISION *Potentiometers*



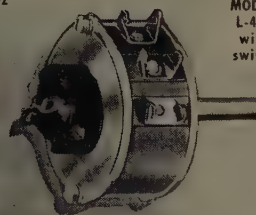
SERIES L-400

DeJUR  
MODEL  
L-402

DeJUR  
MODEL  
L-400  
with  
switch

### FEATURES:

- 1 1/2" diameter
- 3 watts fully enclosed
- 5 to 125,000 ohms
- accuracy up to 0.5%
- linearity up to 0.1%
- 300° rotation mechanical and electrical
- on-off switch
- ganging up to 10 units
- double end shafts available



RA-60  
DeJUR  
MODEL  
275



RA-50  
DeJUR  
MODEL  
260



DeJUR  
MODEL  
281



DeJUR  
MODEL  
292

Built to JAN-R-19 specifications. Other models from 1-3/16" to 5" diameter.



1 1/2" *Panel* INSTRUMENTS

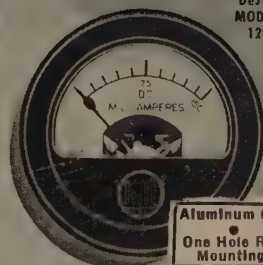
DeJUR  
MODEL  
112

Also available • 2 1/2" • 3 1/2" • 4" panel meters in all standard ranges. JAN-1-6 and A. S. A.

DeJUR  
MODEL  
120

### FEATURES:

Precision built DeJUR 1 1/2" instruments for applications where space must be conserved • DeJUR rugged construction • Both models in all ranges and sensitivities • External shunts and multipliers available for various ranges • Complete magnetic shielding and methods of lighting scale • Approved source for government services meets JAN specifications.



Aluminum Case  
One Hole Ring  
Mounting.

- DC VOLTMETERS
- AMMETERS
- MILLIVOLT METERS
- MILLIAMMETERS
- AC RECTIFIER TYPES (self-contained).

## Power RHEOSTATS

Built to JAN-R-22 specifications, DeJUR Rheostats are available in 25 or 50 watt sizes, single or dual ganged. Resistances up to 50,000 ohms in the 25 watt size and 75,000 in the 50 watt size.



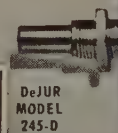
DeJUR  
MODEL  
241

All  
Metal  
Construc-  
tion

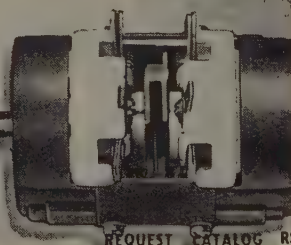


DeJUR  
MODEL  
245

For Further  
Information  
Write  
Dept. R-101



DeJUR  
MODEL  
245-D



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# DeJUR

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✦ From uniform windings to silver-soldering, Resistors, Inc. have established the highest standards in every detail of resistor construction.

And in selection and service . . .

✦ Whether you need one or one thousand units, Resistors, Inc. can furnish the exact resistor you require from the complete range of types, sizes and ratings . . . 5 to 200 watts, fixed, adjustable, ferrule terminal, ribbon-on-edge, and others.

✦ Consult us today on your resistor problem, and request Bulletin 87 for your files.

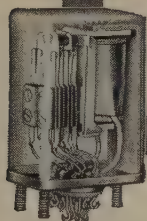
**RESISTORS, INC.**

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**MILITARY and**  
**INDUSTRIAL**  
**RELAY**  
**PROBLEMS**

**APPLICATIONS UNLIMITED:**

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- Sensitive
- Miniature
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- Telephone
- Aircraft
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Complete research, development, type testing, and manufacturing facilities are at your service. Models and pilot runs can be completed quickly and at very reasonable cost. Production capacity—10,000 relays per day. Send specifications for samples, recommendations and quotations. Catalog available on request.

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## IN CALIFORNIA

If your qualifications are right, there may be a position for you with this securely established, rapidly expanding klystron engineering and manufacturing organization. Here are the people we're looking for:

### PRODUCTION ENGINEERS,

experienced in vacuum tube manufacture and familiar with microwave tubes and devices.

### TECHNICIANS

with good electronic background in either tube production or research and development work.

### TUBE PRODUCTION MECHANICS

Experienced mechanics who understand the machines and equipment used in vacuum tube manufacture, and can operate and maintain them.

### TECHNICAL WRITERS

with EE degree or good electronic background and at least one year's experience planning and writing reports and instruction books to government specifications.

These jobs combine attractive living in the San Francisco Bay area (the birthplace of electronics), the stimulation of a fast-growing center of electronic activity, good pay and other benefits, challenging opportunity for advance, and the satisfaction of ownership participation.

Come and visit our Booth 55 at the New York IRE Show, or write for further details to Personnel Director.

**VARIAN ASSOCIATES**

990 Varian Street, San Carlos, California

See us at booth No. 240, I.R.E. Show, Grand Central Palace, March 3-4-5-6

(Continued from page 181A)

## Proportional Counter

A new Alpha-Beta-Gamma proportional counter, embodying many new features, is now available from **Nuclear Measurements Corp.**, Indianapolis 18, Ind.



One of its most important features is unusual effectiveness for counting soft betas (an improvement in yield over thin window G-M tubes of about 10 times for  $C^{14}$  and  $Ca^{45}$ ). Roughly the same range holds for the sulfur isotopes, but for these short half-lives the instrument is effective for 3 to 6 additional half-lives.

The specifications are: background, alpha 5 c/hr; beta 45 c/m; geometry, 2 pi for alpha and beta; resolution loss, 1 per cent per 100,000 c/m.

A 55 minute precision timer is built into the instrument. The plateaus are: alpha, 1,000 to 1,300 volts; beta 1,600 to 1,900 volts; slope is  $\frac{1}{2}$  per cent for the best 100 volts.

The price is \$895.50 F.O.B. the factory.

(Continued on page 184A)

## 28 years of service to

the Radio, Electronic and Communications Industry

## BAUMAN & BLUZAT

- Condensers
- C.T.C. Radio Hardware
- Selenium Rectifiers
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All Phones—HU 6-6809-10-11-12

# A NEW Way to Measure Flux-DYNA-LABS., Inc., D-79 GAUSSMETER



- Reads 10 to 30,000 Gauss Flux Fields
- No Pull Needed—Steady Meter Reading
- Probe only .025" Thick
- Active Area .01 sq. in.
- Probe Does Not Distort Field
- Vector Field Measurements Obtainable
- Non-Uniformity Quickly Established
- Special Probes Readily Available
- Production Test Jigs Available
- Size only 13" x 6 $\frac{3}{4}$ " x 10 $\frac{1}{2}$ "
- Net Weight 10 $\frac{1}{2}$  lbs.
- Power Supply 105-125 V, 50-60 cycles

For the first time there is now available an instrument which can handle all of your magnetic measuring problems. From an extensive background of precision design and manufacture of miniature magnetic earphones and other electro-acoustic devices Dyna-Labs., Inc. designers have produced an instrument of remarkable flexibility.

With this one instrument, the D-79 Gaussmeter, flux density can be measured, direction of flow determined, stray fields located and measured, variations in strength plotted, and production lots checked against a standard.

Simple to operate: No Ballistic readings—no jerk—no pull.

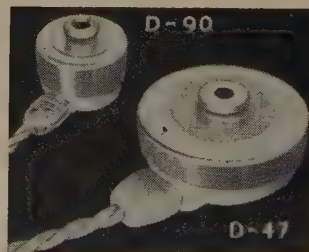
Almost any field can be entered because our D-79 probe is only .025" thick.

Whatever your problem—D-79 can solve it!

Write today for further details—Dept. 2P



SHOWN BELOW FULL SCALE ARE STANDARD SIZE AND SUB-MINIATURE HEARING AID EAR-PHONES.



## DYNA-LABS., Inc.

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COrtlandt 7-1275

WORLD'S FOREMOST MANUFACTURER OF MINIATURE MAGNETIC EARPHONES

# Test Equipment

FOR  
RADAR and PULSE  
APPLICATIONS

## Model 705 WOBBULATOR

... for RF, IF, and Video Amplifier  
alignment and measurement



- Center Frequency of Swept Band—2.0 mc to 500 mc.
- Swept Bandwidth—up to 100 mc wide.
- Output—0.1 volt at 50 ohms, with calibrated continuously variable 90 db output attenuator to allow rapid, accurate gain measurement.
- Internal five inch CRT display of response of circuit under test; 0.05 mv. or more input to the high or low impedance probes from the circuit under test will give an adequate pattern.

Write  
for complete  
technical data

# Canoga

Corporation

5955 Sepulveda Blvd., Van Nuys, Calif., Box 361

## RREP 840-A FM Transmitter

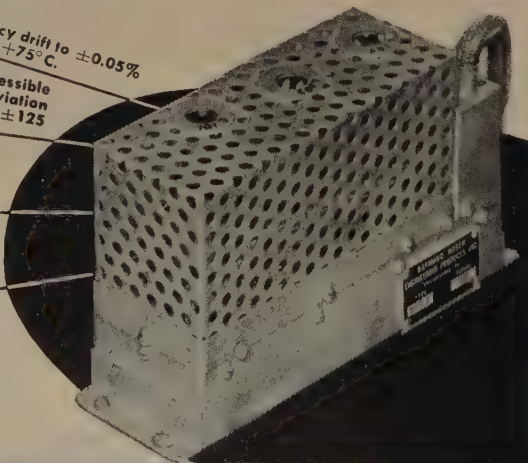
Light in weight, small in form factor, the 840-A FM Transmitter has been developed for airborne applications in the flight test field. This precision instrument incorporates many outstanding features, with excellent performance even under extremes of acceleration, vibration, temperature and high altitude.

Compensation to restrict center frequency drift to  $\pm 0.05\%$  within temperature range of  $-10^{\circ}\text{C}$  to  $+75^{\circ}\text{C}$ .

215-235 MC range—easily accessible controls  $\pm 150$  KC maximum deviation low distortion (less than 1.0% at  $\pm 125$  KC deviation).

3-watt minimum output over entire tuning range, with low input power requirements.

Extremely low noise component due to ruggedized construction and the unique engineering techniques employed.



RREP

RAYMOND ROSEN ENGINEERING PRODUCTS, Inc.

32nd & Walnut Streets • Philadelphia 4, Pa.

## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.  
(Continued from page 183A)

### Plant Expansion

David H. Cogan, President of CBS-Columbia Inc., 170 53 St., Brooklyn 32, N. Y., announced the purchase of approximately 275,000 square feet of additional manufacturing space for the production of television and radio receivers. He stated that this is the first step in CBS-Columbia's multi-million dollar expansion program.



With the company's present manufacturing facilities in Brooklyn, this new plant located in Long Island City, N. Y., will make available a total of over 500,000 square feet of manufacturing space for civilian and military production requirements.

The manufacturing layout will utilize complete conveyorization of all phases of production, including a self-contained metal fabricating and plating division, a component division, and a cabinet division that will be completely equipped with high speed woodworking machines, electronic assembly, and provisions for a direct flow of cabinets to the assembly lines.

### 21-Inch TV Picture Tubes

Two new all-glass 21-inch rectangular TV picture tubes are now available from the Cathode-ray Tube Div., Allen B. Du Mont Laboratories, Inc., Clifton, N. J. The new tubes offer several important advantages over previous 21-inch designs.



The new tubes are designated as the Type 21EP4A and the Type 21KP4A. Both types employ the same all-glass bulb which results in a picture area of 242 square inches larger than previous metal-cone 21-inch tubes. The screen face is made of filter glass which minimizes re-

(Continued on page 185A)

## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 184A)

flections and improves contrast.

The Type 21EP4A employs the Du Mont bent-gun for electromagnetic focusing. A single-magnet ion trap is used. Type 21KP4A is one of the new Du Mont Selfocus Teletrons requiring no focus controls or circuitry. It provides absolute focus at all times. The 21KP4A may be used as a replacement for either electromagnetic or electrostatic focusing type tubes.

Both of these new tubes are available for delivery to either original equipment manufacturers or to the trade for replacement and conversion work.

### Catalog

• • • **Allied Radio Corp.**, 833 W. Jackson Blvd., Chicago 7, Ill., announces the publication of the new 1952 catalog. Its 212 pages, covering "Everything in Radio, Television, and Industrial Electronics," place special emphasis on equipment for industrial maintenance, research, and production requirements. All the products of this Chicago jobber are listed in the catalog.

(Continued on page 186A)

## SECON development and production METALLURGISTS

**BASE, RARE AND PRECIOUS METALS AND ALLOYS**

**SMALL UNITS**

**SMALL SIZES**

**CLOSE TOLERANCES**

Nickel alloy, filament wire and ribbon: flat, grooved, crowned.

Grid wire electroplated.

Alloys for special requirements, bare or enameled.

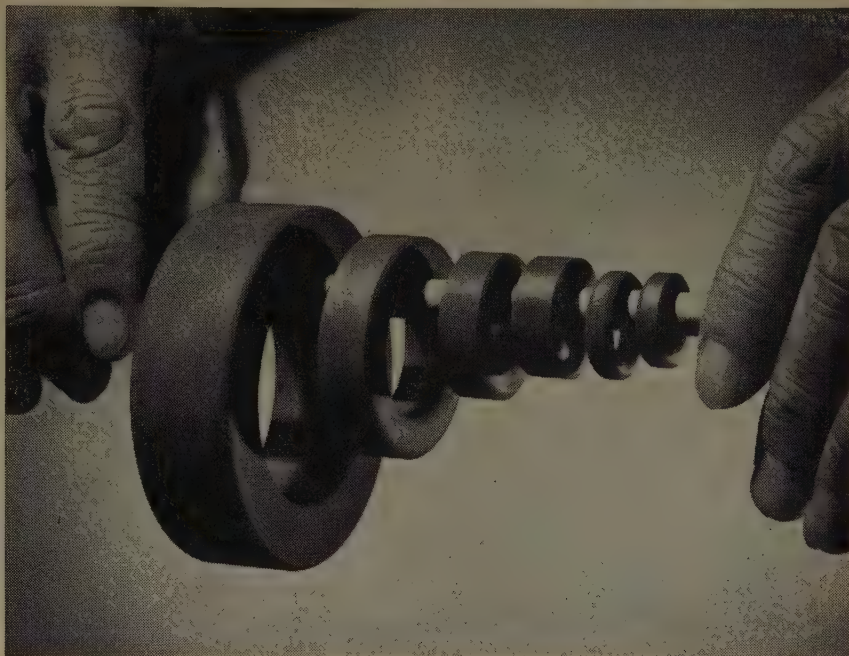
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Further details upon request.

**SECON**

**METALS CORPORATION**  
228 East 45th Street, New York 17, N. Y.  
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## POWDERED-IRON TOROIDS



**3.375 in.**

outside diameter to

**0.800 in.**

**PRECISION-MOLDED** Lenkurt Toroids offer exceptional magnetic and temperature stability, extremely low losses and cross-modulation products. They are available in a variety of powdered-iron materials and on extremely short delivery schedules. Costs are low—thanks to new high-speed production facilities now in operation.

**FIVE POPULAR SIZES** of toroids are produced rapidly from existing dies, usually are available directly from stock. Lenkurt's magnetic-component engineering group is ready to solve special problems of inductor design, produce special sizes or types of toroids, as well as pot cores, cup cores, or tuning slugs to your specifications. *Send for further details.*

**LET LENKURT QUOTE** on your specific needs for: Toroidal coils — Filters — Powdered-iron cores — Specialized transformers — Variable inductors — and Toroidal transformers, made by Lenkurt Electric Company—*largest independent manufacturer of telephone toll transmission equipment.*

**LENKURT ELECTRIC SALES COMPANY**



San Carlos 2, California

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 185A)

## Nylon Retaining Rings For Coil Forms

Through the use of nylon-phenolic terminal retaining rings, the Cambridge Thermionic Corp., 456 Concord Ave., Cambridge 38, Mass., now extends the scope of its ceramic coil forms. Nylon-phenolic in no way impairs the moisture and fungus resistant qualities of the coil form assemblies.



These rings are good for bifilar windings. Four separate terminals, two on each nylon-phenolic ring, mean secure individual connections for each coil lead.

Terminals can be located above or below winding to shorten wiring to circuit elements. The shape of terminals affords two soldering spaces on each to segregate coil terminations from the circuit wiring. Firmly cemented nylon-phenolic rings keep the terminals in exact position.

The nylon-phenolic rings show an increase in Q over metallic rings.

All materials and finishes meet government specifications. Rings are available with LST, LS5, LS6 coil forms.

## Pulse Generator

The Model D-2 Calibrator is an improved version of the Model D-1 developed by Rutherford Electronics Co., 3707 S. Robertson Blvd., Culver City, Calif.

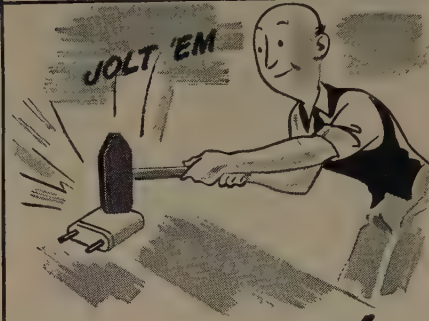
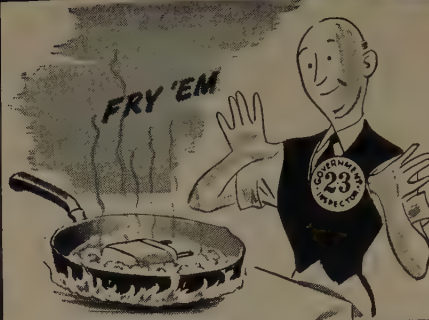
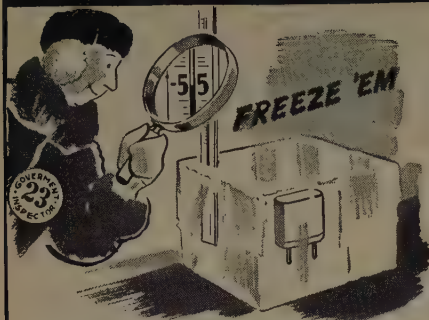


The Model D-2 Calibrator has 17 different pulse rates available at the output connections. Coincidence circuits are employed to render negligible the phase lags between the various outputs.

Simultaneous outputs having the following pulse spacings are available: 10, 100, 1,000, 10,000, and 100,000 microseconds. In addition, a selection of one of the following pulse spacings is available:

(Continued on page 188A)

# They can take it!



**DX  
XTALS**

THE HEART OF A GOOD TRANSMITTER

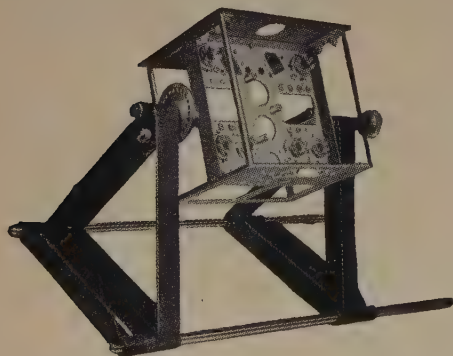
*-and dish it out!*

**DX RADIO PRODUCTS CO.**

GENERAL OFFICES: 2300 W. ARMITAGE AVE., CHICAGO 47, ILL.

**SPEED** your assembly lines with  
our

## WIRING FIXTURES



1. Can be loaded and unloaded in two seconds.
2. Indexed 360° fixture to hold chassis in any position to step up soldering and all other assembly operations.
3. Adjustable to any size to base limits of the Jig.
4. Sturdy, rigid construction.
5. Holding adapters to fit your chassis.
6. Saves spoilage.

LOOK US  
UP AT  
BOOTH 351  
I.R.E. SHOW  
GRAND CENTRAL  
PALACE

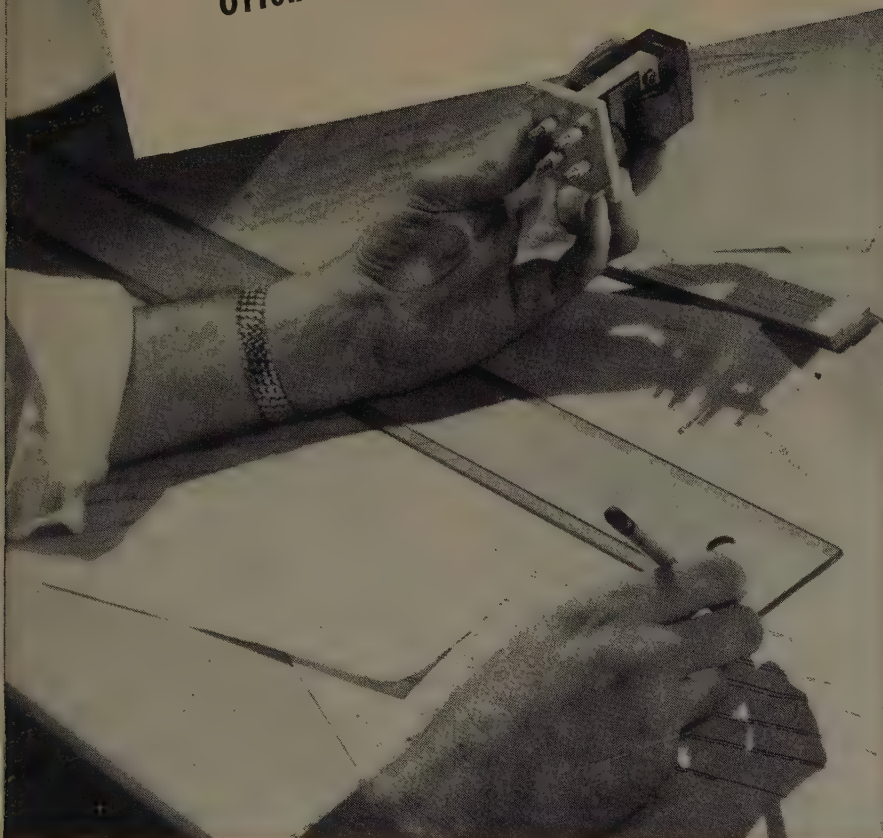
**SPECIAL DESIGNS** to solve your production problems. We invite your inquiry.  
*Write or Wire for detailed information and literature.*

**PRODUCTION TOOL & FIXTURE CO.**

37 WEST MAIN STREET, OYSTER BAY, N.Y.

# ORTHOSIL...

Oriented Thin Steel Laminations



OrthoSil is Thomas & Skinner's new 4 mil orthographic iron-silicon laminations for high frequency inductors. The laminations have exceptionally high permeabilities from very low to very high inductions with correspondingly low core losses. OrthoSil is oriented to provide directional magnetic characteristics.

Developed primarily for frequencies of 400 to 2000 cycles, these thin laminations are also adaptable to the audio ranges.

Thomas and Skinner is producing

OrthoSil laminations in standard as well as in special shapes. Our UI and EE series are designed especially for the OrthoSil, and are excellent for 400 cycle applications. These silicon steel laminations will frequently replace scarce nickel materials.

Transformers, such as power and 3 phase, chokes, saturable reactors and filters are but a few of the many electrical components for which OrthoSil is designed.

Write today for bulletin giving electrical characteristics and other pertinent data on OrthoSil oriented laminations.

Specialists in Magnetic Materials—Permanent Magnets and Laminated Cores



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### Electronic Fundamentals and Applications

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Complete, logical, easy-to-follow treatment of (a) physical principles underlying electron tubes, (b) characteristics of vacuum tubes, (c) all basic tube circuits. Includes: Electron Ballistics, Cathode-Ray Tubes, Emission of Electrons, Space Charge in Vacuum Tubes, Diode Rectifiers, Triodes, Multi-Element Tubes, Small-Signal Amplifier Circuits, Audio-Frequency Amplifiers, Radio-Frequency Amplifiers, Oscillator Circuits, Modulation Systems, Wave-Shaping Circuits, Gaseous Conduction, Gas Diodes, Gas Control Tubes and Circuits, Photoelectric Cells, Solid-State Electronics.

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### Elements of Television Systems

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Complete basic theory, plus current practice, covering: Closed TV Systems, Commercial Telecasting Systems, Color TV Systems. Gives clear exposition of all phases of picture transmission, including the new technique of dot interlace.

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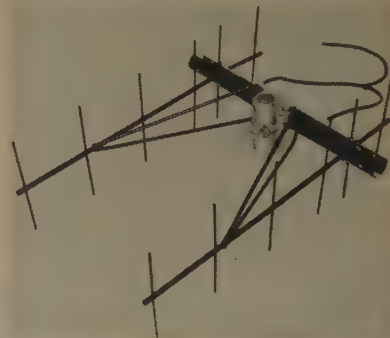
These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 186A)

20, 50, 200, 500, 2,000, 5,000, 20,000, 50,000, and 200,000 microseconds. A selection of pulses is also available for calibration purposes. Some of these (designated by "W" after the repetition period) are produced by a single-shot multivibrator having a pulse width which is a function of the repetition period. They are 10, 100, 100W, 1,000, 1,000W, 10,000, 10,000W, 100,000, and 100,000W microseconds. The Calibrator, mounted on a standard relay rack panel, has a cover of stainless steel with hardwood end frames. Over-all dimensions: 9 inches high by 19½ inches wide by 15 inches deep.

## Communications Antenna

High gain and rugged construction are features of two new directional antennas for the 450 to 470 mc. band, manufactured by The Ward Products Corp., Div. The Gabriel Co., 1523 E. 45 St., Cleveland 3, Ohio.



Model SPP-161 (illustrated) is a 12-element Yagi-type antenna with a gain of 11 db. It is vertically polarized for commercial communications (with provision for horizontal polarization where necessary), matches 52 ohms with VSWR of less than 2 to 1, and can handle up to 250 watts of power. Model SPP-172 is a 24-element Yagi of construction similar to the SPP-161, and has a forward gain of 14.5 db. Both units are supplied with matching harnesses.

Construction is of paint-finished, copper-plated steel. The antennas are shipped pre-assembled for rapid installation.

Models SPP-161 and SPP-172 are designed for point-to-point communications in broadcasting, railroad, petroleum-pipe line, forestry, utility, and state police fields.

A descriptive bulletin can be secured from radio distributors or from Ward Products.

## Telemetering Records

A new magnetic tape recorder, especially designed for recording signals telemetered from aircraft and missiles, is announced by the Ampex Electric Corp., 934 Charter St., Redwood City, Calif. This

(Continued on page 189A)



**ANSWERS YOUR  
PILLOW  
SPEAKER  
PROBLEM!**

**PICTURED IN  
ACTUAL SIZE!**

3" diameter, 7/8" thick


A compact speaker-microphone with a thousand uses that makes your product more saleable.

The Wright-Zimmerman Model 300 Dynamic Reproducer is virtually indestructible, attractively styled and light as a feather. Ideal for personalized pillow speaker use with excellent tone and as a dynamic microphone.

Protected under Patent #2523802—  
Other Patents pending

**NEW PATENTED  
MODEL 300 DYNAMIC  
PILLOW SPEAKER**

**Wright  
Zimmerman Inc.**  
NEW BRIGHTON, MINN.



**FS MICROMETER HEAD**  
*for the Electronics Industry*

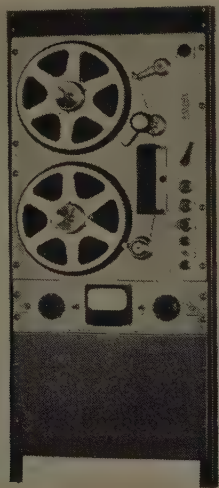
ELECTRONIC ENGINEERS PRAISE FS MICROMETER HEADS FOR THEIR PRECISE ACCURACY EVEN AFTER LONG HARD USAGE. THIS ACCURACY IS MADE POSSIBLE BY A PATENTED THREAD-FORM WITH RADIAL-LOADED NUT FOR ELIMINATION OF BACK-LASH, AND AUTOMATIC WEAR COMPENSATION . . . OTHER FEATURES AND SPECIFICATIONS ARE DESCRIBED IN OUR NEW BULLETIN, OBTAINABLE ON REQUEST.

**FREQUENCY STANDARDS**  
P. O. BOX 66, EATONTOWN, N. J. • TELEPHONE ASBURY PARK 1-1018

# News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.  
(Continued from page 188A)

recorder, known as Model 307, is the second of a line of special recorders designed for recording original telemetered data. The new recorder has a frequency range of from 100 to 100,000 cps, thereby permitting the recording of all FM/FM telemetering channels recommended by the Telemetering Panel of the Research and Development Board.



The new recorder is designed for three tape speeds: 60 inches per second in addition to the usual 30 and 15 ips. The major application will be in the recording of FM signals which contain measurement data made on aircraft or missiles during flight which must be recorded on the ground.

The extended frequency range of this unit makes it useful for recording many types of data which previously could be recorded only by means of a cathode-ray oscilloscope and moving film camera.

The rack Model 307-R (stock #MP-1886-R) is \$2,250.00 F.O.B. factory.

## Catalogues

•••A new 12-page engineering bulletin, entitled "Introduction to the Application of 'Ferroxcube'," is now available from the Advertising Dept., Ferroxcube Corp. of America, Saugerties, N. Y. This bulletin, FC-5100, gives basic data on the use of ferromagnetic ferrites as magnetic cores in electronic and electrical circuits. It is of particular interest to designers of coils and RF inductors. Among the subjects discussed are the effects of copper, eddy current, hysteresis, and residual losses in magnetic materials as they pertain to inductor design.

•••A new electrode-selector chart, listing the proper electrodes to be used in the welding of various metals, has been announced as available from the General Electric Co., Schenectady 5, N. Y.

The new bulletin (GEC-657B) is designed to present up-to-date condensed information on recommended electrodes for the welding of mild steel, stainless steel, low-hydrogen low-alloy steels, low-alloy high-tensile steels, cast-iron, bronze, and other metals.

(Continued on page 190A)

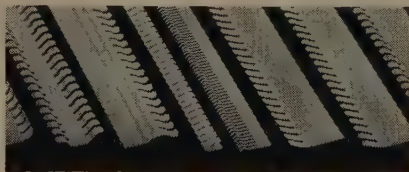


■ **ENGINEER'S MICROWAVE KIT** . . . saves time and money in development work. Contains 9 beryllium copper, jig-hardened circular contact rings and 6 finger contact strips.

*Micro-Processed\**

## Beryllium Copper Springs

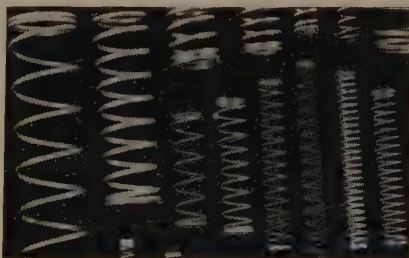
to help solve your radio-electronic problems



■ **FINGER CONTACT STRIPS** . . . for electronic equipment—available in a variety of contours without tool cost. Length—width—mounting holes—and finish optional. For information—Write for Bulletin B-52.



■ **CONTACT RINGS** . . . standard—and made to order. Truly circular—to insure equal pressure from all fingers. For information—write for Bulletins C-52 and D-52.



■ **COIL SPRINGS** . . . the finest available combination of high strength and uniformity. Made to your specifications.



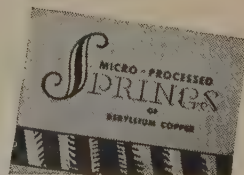
■ **MINIATURE SOCKET AND PLUG BOARD CONTACTS** . . . produced with automatic tooling. Pressure on plug pins and tab ductility controlled within close limits.

■ **ENGINEER'S ASSORTMENT** . . . 100 beryllium copper helical compression springs . . . 50 pairs—all different.

## Instrument Specialties Company, Inc.

■ 232 BERGEN BOULEVARD, LITTLE FALLS, NEW JERSEY  
Telephone Little Falls 4-0280

\*For full information on I-S Micro-Processed Springs—write for your copy of Catalog No. 7—"Micro-Processed Springs of Beryllium Copper".



## RCA INSTITUTES also "Sets the Pace."

For more than 40 years the Institutes has been training men and women for industry.

The RESIDENT SCHOOL offers intensive Courses embracing all phases of radio and television technology.

**ADVANCED TECHNOLOGY T3** . . . laboratory development in radio electronics; testing; radio and TV broadcasting; receiver servicing. High School graduation a prerequisite.

**RADIO-TV BROADCASTING V7** . . . operating radio and television broadcasting stations; laboratory work; receiver servicing.

**RADIO & TELEVISION SERVICING V3** . . . installation and servicing of all types of radio-TV receivers.

**ADVANCED TELEVISION SERVICING V8** . . . training in the circuits and repair of the latest types of TV receivers, including extensive practice in the location and correction of faults and failures.

**COMMERCIAL RADIO OPERATING V5** . . . Station operating in marine, mobile, and point-to-point communications.

**INTERNATIONAL MORSE CODE V4** . . . for beginners and operators who desire to renew or increase code speed.

The HOME STUDY COURSE IN TELEVISION SERVICING offers practical down-to-earth instruction in TV servicing to persons in the industry.



For literature describing ALL COURSES, write or phone:

# RCA INSTITUTES, INC.

A Service of the Radio Corporation of America

Dept. I 252

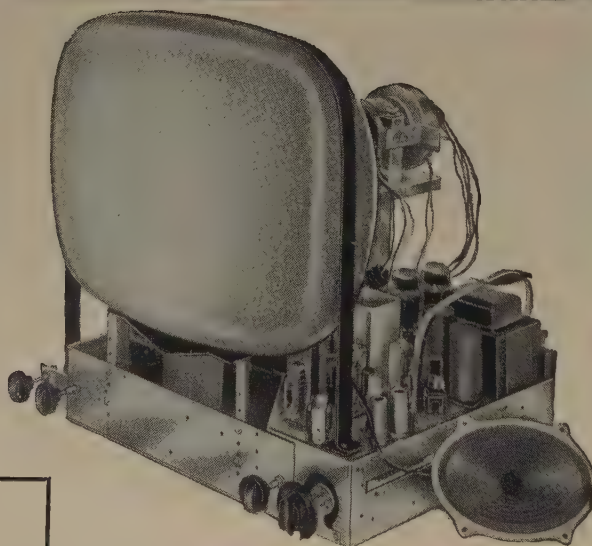
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Watkins 4-7845

# TECH-MASTER

# TELEVISION

TECH-MASTER is recognized by TV engineers and technicians as representing the highest calibre of television engineering.



See the latest TECH-MASTER TV developments at our Booth No. 267 at the I.R.E. Show

For complete information on TECH-MASTER products see your jobber or write Dept. IR-2.

## TECH-MASTER PRODUCTS CO.

443-445 Broadway, New York 13, N. Y.

More leading engineers and technicians have built Tech-Master for their own use than any other Television Kit.



## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.  
(Continued from page 189A)

### Catalogues

• • • A 12-page Illustrated Price List on instruments and accessories for radioactivity measurements is available from **Radiation Counter Laboratories, Inc.**, 5122 W. Grove St., Skokie, Ill.

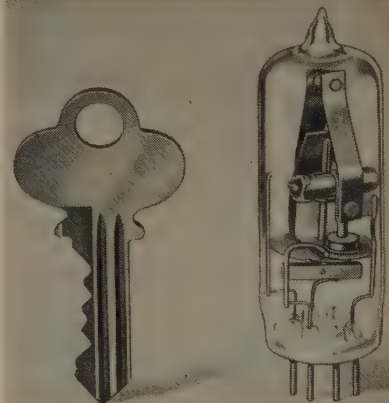
This list shows scalers, nucleometers, rate meters, scintillation counters, scintillation crystals, water monitors, health protection instruments, Geiger-Mueller and proportional counters, flowing gas counters, shields, absorbers, holders, warning placards, micropipets, and special gases.

• • • A new 4-page bulletin on electronic contour follower systems for machining irregularly shaped parts, has been announced as available from the **General Electric Co.**, Schenectady 5, N. Y.

The publication, designated as GEA-5660, covers one, two, and three-dimension tracer control systems for use on lathes, boring mills, milling machines, drilling machines, etc. Employing many photographs and diagrams, it gives a brief description of each of the systems, its components, features, and operation.

### Miniature Thermal Timing Relay

**Thomas A. Edison, Inc.**, Instrument Div., West Orange, N. J., has announced a new sealed-in-glass miniature thermal relay designed to economize on space and weight.



Model 207 is hermetically sealed in a T-5½ glass envelope with a miniature button 7-pin base. The weight is ½ ounce, seated height is 2¼, diameter ¾ inch. Delay periods range from 5 to 120 seconds, standard heater voltages are 6.3, 27.5 and 115 v ac or dc. Contacts are rated at 2.5 amperes 125 v ac or 1.0 amp 125 v dc. Ambient compensated from -60 to +85°C.

This miniature is particularly adaptable to airborne equipment in such applications as cathode protection in electronic tubes, gyro erection in autopilots, over-voltage and over-current protection, holdovers and integration.

Price range is from \$3.50 to \$7.50.

(Continued on page 192A)

*In New England...*

**Qualified**  
**ENGINEERING ASSISTANCE**  
and  
**COOPERATION**  
IN THE FOLLOWING LINES:

**BUD**

Sheet metal products—  
air capacitors—coils

**CLAROSTAT**

Precision potentiometers—  
standard controls—resistors

**FREED**

Transformers—Laboratory  
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**WALTHAM HOROLOGICAL**

R.F. Connectors—Phone plugs

**SEALTRON**

Hermetic seals

**PERMOFLUX**

Speakers—sound specialties

**TURNER**

Microphones

**WILKOR**

Carbofilm resistors

**26 YEARS OF SERVICE TO  
NEW ENGLAND'S  
ELECTRONIC INDUSTRY**

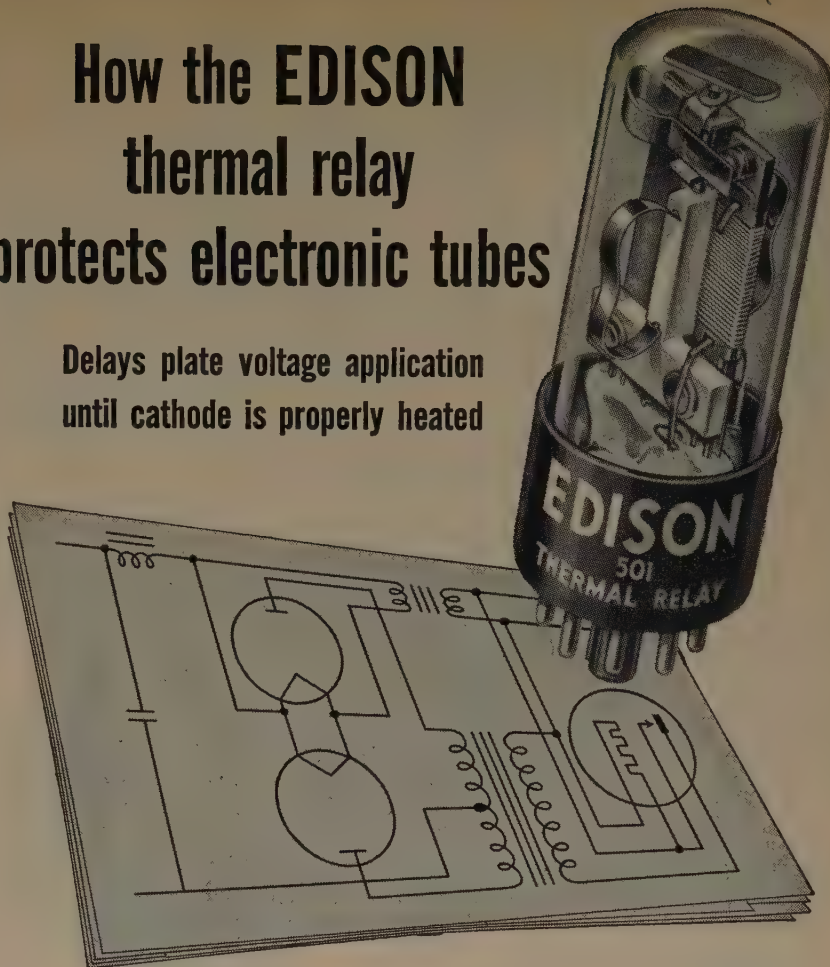
**We invite your inquiries**

**HENRY P. SEGEL**  
*Company, Inc.*

143 Newbury Street  
BOSTON 16, MASS.  
PHONE: KEnmore 6-3012  
Our IRE Headquarters  
Hotel Lexington

# How the EDISON thermal relay protects electronic tubes

**Delays plate voltage application  
until cathode is properly heated**



**PROTECTION OF CATHODES** in electronic tubes, such as thyratrons and gas filled rectifiers, depends on allowing cathodes to reach operating temperature rather than delaying application of plate voltage for a fixed time. A thermal relay, since its operation also depends on attaining a predetermined temperature, is eminently suitable for cathode protection.

**THE EDISON THERMAL RELAY** is widely used for this purpose because (a) its delay characteristics vary with line voltage as does cathode heating; (b) it is suitable for continuous operation; (c) it offers sustained accuracy; (d) it has a wide range of delay

periods; (e) it is silent and positive in operation; (f) it is as independent of ambient temperatures as the cathode it is protecting; (g) it is relatively inexpensive; (h) it is small and lightweight. The cooling rate of the EDISON Thermal Relay prevents loss of equipment operating time due to momentary power interruptions.

**EDISON ENGINEERS** will help you solve your cathode protection problems if you will write and give them the data.

Just address Instrument Division,  
**THOMAS A. EDISON, Incorporated**, 94  
Lakeside Ave., West Orange, New Jersey.

*Thomas A Edison*  
**INCORPORATED**

Instrument Division • West Orange, New Jersey

**OTHER INSTRUMENT DIVISION PRODUCTS**

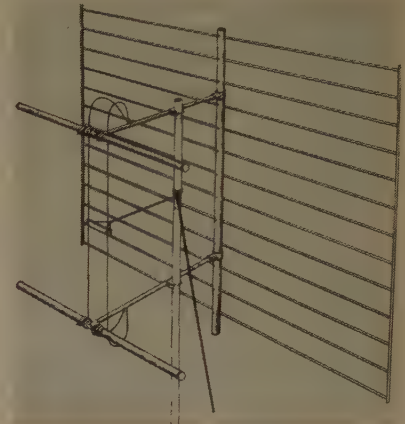
*Sealed Time Delay Relays • Sensitive Relays • Electronic Temperature  
Controls • Critical Temperature Monitors • Electrical Resistance Bulbs.*

**YOU CAN ALWAYS RELY ON EDISON**

(Continued from page 190A)

## TV Antenna

Latest addition to the line of fringe-area TV antennas manufactured by the Gon-Set Co., 72 Tujunga Ave., Burbank, Calif., is their RADARRAY model C. This array is designed to give (on all present TV channels) a clean directivity pattern with high front-to-back ratio, a good impedance match, and high gain. The gain and front-to-back ratio are greatest on the high channels where most needed, but are still high on all low channels.



On the high band, the array functions as four half-wave dipoles in phase, spaced  $\frac{1}{2}$  wave ahead of the reflector screen.

On the low band, shorted stubs across the dipole elements lower the fundamental resonant frequency, and at the same time provide a good impedance match on the low channels. These stubs are quarter wave resonant on the high band and therefore have negligible effect upon high band operation. Reflector spacing approximates a quarter wave length on the low band.

## Continuously Variable Delay Line



Advance Electronics Co., P.O. Box 394, Passaic, N. J., announces the first commercially available distributed-parameter line capable of providing continuously variable time delay from zero to 0.6 microsecond. The firm claims that the transmission characteristics are superior to those of

(Continued on page 193A)

## Twists in Magnesium by Resonant

The forming process adapted by Resonant Company in processing magnesium waveguide has produced some remarkable results. The shapes shown here are accurately produced on a production basis.

When special or variation of types are required, Resonant Company has the design and manufacturing skills to produce them in minimum time.



### Resonant Products Include:

REFLECTORS • FEEDHORNS • ROTARY JOINTS • RF SWITCHES • WAVEGUIDE SECTIONS  
MIXERS AND DUPLEXERS, IN ALL RADAR FREQUENCIES, IN MAGNESIUM OR BRASS

**THE RESONANT CO.**

P. O. BOX 276, BELMONT, CALIF. • PHONE LYtel 3-6286

# News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 192A)

electron-tube delay circuits, ultrasonic lines, or other delay systems. Some of the advantages of this line are freedom of time jitter, fast rise time, no limit on repetition frequency, greater bandwidth, and good transient response. Type 302 may be used for distance measurements in radar or loran systems, for establishing coincidence of sweep and input signal in high-speed oscilloscopes, and for measuring time interval with accuracy better than a small fraction of a microsecond.

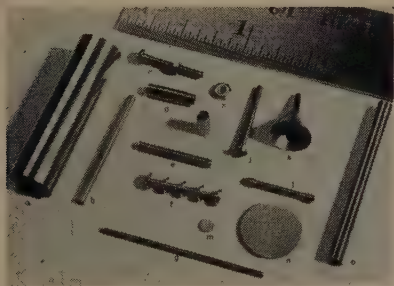
The rise time is  $0.00082 \sqrt{t}$  microsecond, where  $t$  is the amount of delay in millimicrosecond.

The characteristic impedance is 960 ohms nominal.

The attenuation in db per 100 millimicrosecond delay is: approximate zero below 1 mc, 0.3 at 5 mc, 0.95 at 10 mc, 1.3 at 20 mc, and 1.5 at 30 mc.

## Tungsten Machining Technique

A new technique for drilling, grinding, turning, milling, threading and tapping tungsten metal using ordinary metal working machines has been developed by Phillips Laboratories, Inc., Irvington, N. Y.



According to an announcement by Dr. O. S. Duffendack, this new technique permits the machining of tungsten metal to tolerances comparable to those normally achieved with steel or brass. Tungsten tubing has been fabricated with an outer diameter of 0.066 inch  $\pm 0.0005$ , and an inner diameter of 0.060 inch  $\pm 0.001$ . An 0-80 tungsten screw 11/16 inch long has been made with a 0.025 inch hole drilled through its entire length.

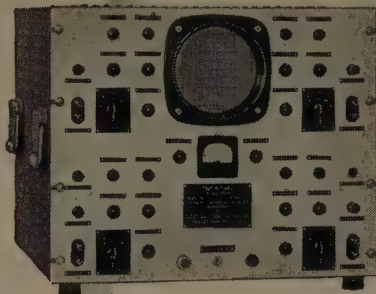
The Laboratory is using this method in manufacturing its newly developed tungsten L-cathodes for long-lived electron tubes. Additional applications are expected to be found in electron tube manufacture and in the fabrication of parts of other devices which must operate at exceedingly high temperatures in a vacuum, or in reducing or inert atmospheres.

The new machining technique was developed by Dr. Roberto Levi, a research chemist on the Laboratory staff.

(Continued from page 194A)

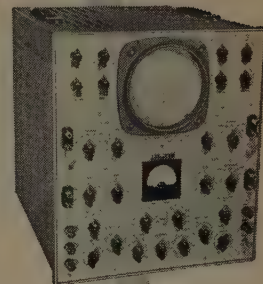
Type 5JP11A  
Single-gun  
tube

Type 54SWP11  
4-gun tube



Oscilloscope  
for strip-film  
recording

H-21 Dual-channel  
Oscilloscope



## ...for more accurate and efficient RESEARCH, TEST and VISUAL OPERATING CONTROL

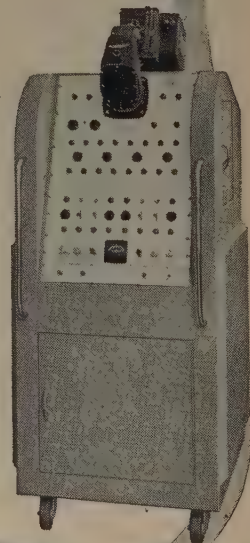
By permitting simultaneous observation or recording of 2, 4, 6 or more different phenomena, ETC multi-gun cathode ray tubes and multi-channel oscilloscopes pave the way to farther-reaching analysis and better operation in many fields.

*New catalog on request.*

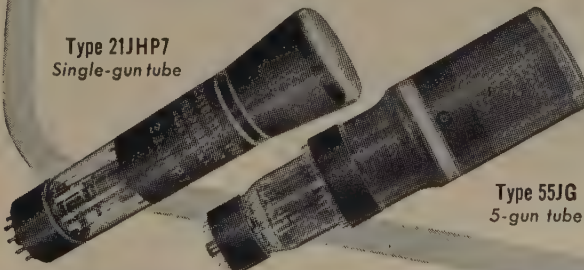


H-81 8-Channel Oscilloscope  
originally developed for recording  
seismographic phenomena

H-42A Strainalyzer  
for simultaneous  
analysis of 4  
stresses or  
strains from  
0 to 50,000  
cycles



Type 21JHP7  
Single-gun tube



Type 55JG  
5-gun tube

*electronic tube corporation*

1200 E. MERMAID LANE, PHILADELPHIA 18, PA.

**FUNGUS-PROOF**

# NYLON LACING CORDS

meet ARMY-NAVY and CIVILIAN Requirements

• Intensive research in the laboratories of Heminway & Bartlett has resulted in the development of a fungus-proof Nylon Lacing Cord. This new cord—with its special synthetic resin coating—resists the growth of mold and micro-organisms, factors most often responsible for the deterioration of old type linen and cotton lacing cord and the subsequent corrosion and failure of electronic equipment.

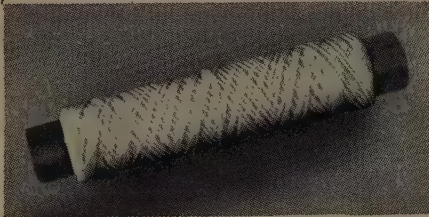
Heminway & Bartlett's new special finish Nylon Lacing Cord has high abrasion resistance... low moisture absorption. It retains the desirable malleability of wax and yet has a melting point of over 190° F.

It is non-toxic to humans.  
We'll be glad to send you full information and prices.  
Why not write us today!

Write to Dept. IRE:

The Heminway & Bartlett Mfg. Co.  
500 Fifth Ave., New York 36, N.Y.

Branches: Chicago, Boston,  
St. Louis, Cincinnati, San Francisco,  
Charlotte, N.C., Gloversville, N.Y.



LACING CORD (TYING TWINE)

## HEMINWAY & BARTLETT

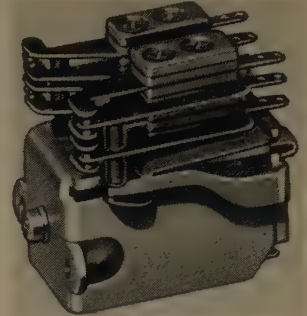
See Us at Booth 327

## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.  
(Continued from page 193A)

### Small Low Power Relay

A small, sensitive relay designed for operation on low power is the new Type "N" Relay, announced by C. P. Clare & Co., 4719 Sunnyside Ave., Chicago 30, Ill.



This relay will operate on less than 50 milliwatts with a 10,000 ohm coil, one Form C contact (spdt) and a standard adjustment. With a 450 ohm coil and four Form C contacts (4pdt) it will operate on 7/10 watt, even under conditions of vibration and high ambient temperature.

Two advantages are high contact pressure (minimum 30 grams), and adequate gap (minimum 0.015 inch).

(Continued on page 195A)

## need GYROS ?



Giannini makes them  
**FREE • VERTICAL • DIRECTIONAL • RATE**

Write us about your gyro problems, both A. C. and D. C.

**G. M. GIANNINI & CO., INC.**  
Pasadena 1, California

## Giannini



**WANTED ★ ★ ★**  
**ENGINEERS,**  
**SCIENTISTS**

*Unusual opportunities for outstanding and experienced men.*

These top positions involve preliminary and production design in advanced military aircraft and special weapons, including guided missiles.

#### IMMEDIATE POSITIONS INCLUDE:

Electronic project engineers  
Electronic instrumentation engineers  
Radar engineers  
Flight test engineers  
Stress engineers  
Aero- and thermodynamicists  
Servo-mechanists  
Power-plant installation designers  
Structural designers  
Electro-mechanical designers  
Electrical installation designers  
Weight-control engineers

Excellent location in Southern California. Generous allowance for travel expenses.

*Write today for complete information on these essential, long-term positions. Please include resume of your experience & training. Address inquiry to Director of Engineering.*

**NORTHROP AIRCRAFT, Inc.**  
33 E. Broadway  
Hawthorne (Los Angeles County) Cal.

## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 194A)

Type "N" Relays are  $1\frac{1}{8}$  inches long,  $1\frac{5}{32}$  inches wide and  $1\frac{1}{8}$  inches high with maximum of ten contact springs. Relays with not more than 14 terminals for coil and contact springs can be hermetically sealed in enclosures of extremely small size.

For complete information, write for Bulletin #109.

### Vacuum-Impregnation of Conductors

A process by which thermosetting resins insulate conductors through vacuum impregnation and reduce leakage in high-voltage conductors has been developed by F. J. Stokes Machine Co., 5500 Tabor Road, Philadelphia 20, Pa.

This vacuum pump manufacturer states that these resins reduce interference from adjacent conductors in closed circuits, and that the process is more efficient than conventional wrapped or tubular insulation.

In using this process, the unit to be insulated is placed in a pressure-tight chamber and the air is exhausted with a high pressure pump. Heated to a liquid state, the resin is introduced into the chamber where it penetrates the smallest openings because all air has been removed from the pores by the vacuum.

(Continued on page 197A)

## WANTED!

Lines of reliable manufacturers of quality test equipment or components to sell in the Metropolitan New York area.

**TWELVE YEARS** of Reliable-, Reputable-, sales engineering is at your service!

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Hughes**  
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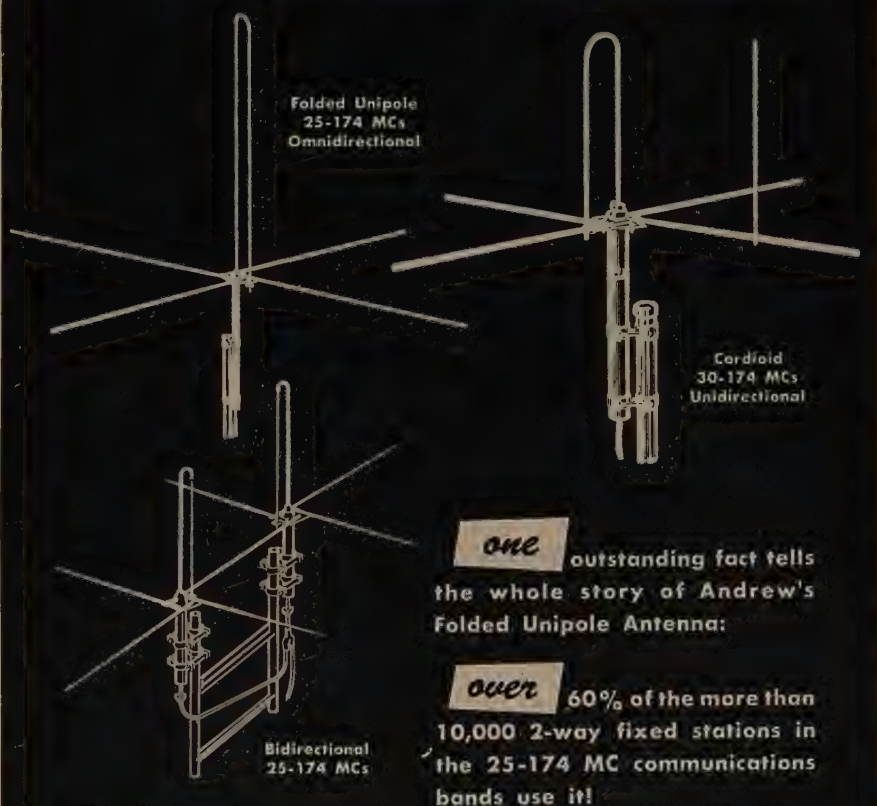
# Andrew

## folded unipole

25-174 MCs

### Outsells

### all others combined!



**one** outstanding fact tells the whole story of Andrew's Folded Unipole Antenna:

**over** 60% of the more than 10,000 2-way fixed stations in the 25-174 MC communications bands use it!

The Andrew Folded Unipole comes in modified versions to provide directional patterns and hurricane resistance. For complete information write for Bulletins 38C and 64.

**Andrew**  
CORPORATION  
183 EAST 75th STREET CHICAGO 19

**ANDREW**

phone Triangle 4-4400

TRANSMISSION LINES FOR AM-FM-TV • ANTENNAS • DIRECTIONAL ANTENNA EQUIPMENT  
ANTENNA TUNING UNITS • TOWER LIGHTING EQUIPMENT

# The 2550 Series ELECTRONICALLY REGULATED POWER SUPPLIES

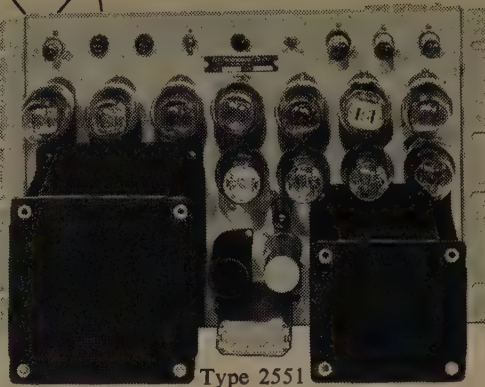
A high quality, heavy duty line of electronically regulated power supplies, specifically designed for broadcast, laboratory and production applications.

## GENERAL SPECIFICATIONS

Output Voltage: 250 Volts DC, regulated • Regulation: 0.1% no load to full load • Ripple: Less than 2 mv peak • Stability: Approximately 0.1% volt change in output for line voltage variation from 105-125 V • Mounting: Standard 19" relay rack panel.

Type 2550: 0-250 mils at 250 volts DC. Panel Height 7".....Price \$225.00  
Type 2551: 0-550 mils at 250 volts DC, Panel Height 12¼".....Price \$300.00  
Type 2552: 0-650 mils at 250 volts DC. Panel Height 12¼".....Price \$350.00

• Complete specifications available on request



Type 2551



Manufacturers of a complete line of TV and Radar Test Equipment

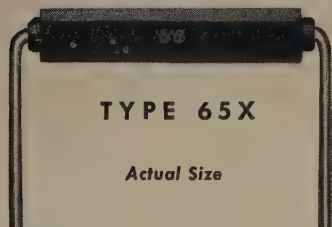
**Tel-Instrument Co. Inc.**

50 PATERSON AVENUE • EAST RUTHERFORD, N. J.

## S.S. White MOLDED RESISTORS



**Of particular interest to all who need  
resistors with inherent low noise level  
and good stability in all climates**



TYPE 65X

Actual Size

### STANDARD RANGE

1000 OHMS TO 9 MEGOHMS

Used extensively in commercial equipment including radio, telephone, telegraph, sound pictures, television, etc. Also in a variety of U. S. Navy equipment.

### HIGH VALUE RANGE 10 to 10,000,000 MEGOHMS

This unusual range of high value resistors was developed to meet the needs of scientific and industrial control, measuring and laboratory equipment—and of high voltage applications.

SEND FOR  
BULLETIN 4906

It gives details of both the Standard and High Value resistors, including construction, characteristics, dimensions, etc. Copy with Price List mailed on request.



**THE S.S. White INDUSTRIAL DIVISION**  
**DENTAL MFG. CO.**



Dept. GR 10 East 40th St.  
NEW YORK 16, N. Y.

WESTERN DISTRICT OFFICE: Times Building, Long Beach, Calif.

# NEW YORK CITY INTERVIEWS

AT THE

**WALDORF ASTORIA**

March 3-6

FOR

## SCIENTISTS & ENGINEERS

Interested in Long Range

## RESEARCH and DEVELOPEMENT on GUIDED MISSILE PROGRAMS

POSITIONS AVAILABLE NOW  
IN FIELDS OF—

RADAR

GYROSCOPES

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MECHANICAL SYSTEMS

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APPLIED PHYSICS and MATH

PRECISION MECHANICAL

DEVICES

ELECTRICAL SYSTEM DESIGN

GENERAL ELECTRONICS

INSTRUMENTATION

MICROWAVES

COMPUTERS

AUTOPILOT

PLAN TO SEE OUR  
REPRESENTATIVES  
MARCH 3-6  
DURING IRE NATIONAL CONVENTION

If Unable To Arrange Interview  
WRITE: Mgr., Eng. Personnel

# BELL

AIRCRAFT CORPORATION  
P.O. BOX 1, BUFFALO 5, N.Y.

## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 195A)

### Instrument Rectifiers Utilize Selenium Cells

Electronic Devices, Inc., Precision Rectifier Div., 429 12 St., Brooklyn 15, N. Y., believes that *Minisel* rectifiers are the first instrument rectifiers made with selenium rectifier cells. This is made possible by a special plate stabilizing process, and by matching the characteristics of the individual cells to give uniformity within and between units. These instrument rectifiers are more efficient than conventional type because they have higher blocking resistances and lower conducting resistances.



*Minisel* rectifiers are manufactured in all standard configurations: (A) half-wave; (B) center-tap; (C) doublers; (D)  $\frac{1}{2}$  bridge; and (E) bridge. The individual cells are rated at 10 v ac input and 5 ma dc output, but can be had in input ratings up to 26 v ac and output current ratings up to 10 ma dc for special applications.

(Continued on page 199A)

### It's New!

#### CML MODEL 1135

##### REGULATED POWER SUPPLY

Here at last is a truly universal power supply that will fill a majority of laboratory applications.

##### OUTPUT #1

Regulated "B" supply in two voltage ranges. 0-150 volts 150-300 volts with a current range of 0-200 MA. Regulation of 150-300 V range better than  $\frac{1}{4}\%$  no load to full load. On 0-150 volt range, regulation from .25 volts to 6 volts .1 volt, improving to  $\frac{1}{4}\%$  from 20 volts to 150 volts. Ripple and noise output less than one millivolt under all operating conditions.

##### OUTPUT #2

0-100 volts regulated "C" bias at zero current output, noise and ripple less than one millivolt.

##### OUTPUT #3

Unregulated 6.3V, 5 ampere heater supply. The Model 1135 is mounted on a standard  $8\frac{3}{4} \times 19$ " rack panel with a chassis depth of 13". The Model 1135-C is housed in a standard rack cabinet for bench use. Write for the new CML catalog describing the Model 1135 and other CML products.

#### Communication Measurements Laboratory, Inc.

120 Greenwich Street, New York 6, N.Y.  
Tel. Rector 2-2080

don't miss the HIGH SPOT

## of the I·R·E SHOW

fourth floor . . . booth 457

## Millivac's *SENSATIONAL* *New Developments*



### MEMO-SCOPE

The Wide Band Scope that records instantaneously and non-photographically.



### LOFYLD POWER TRANSFORMER

Toroidal Type Power Transformer with minimum magnetic field radiation.

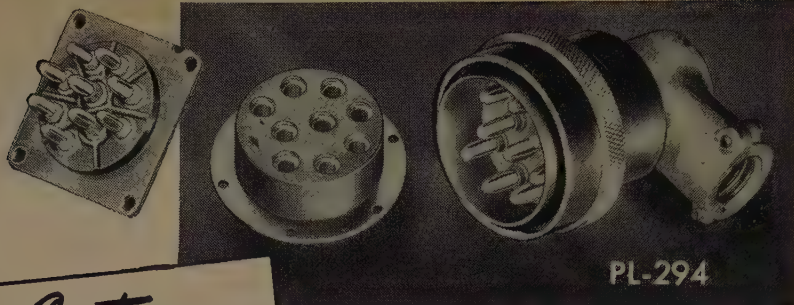


### AC MICRO VOLT METER

A new sensitive VTVM that satisfies both logarithmic and linear scale requirements.

MILLIVAC Instrument  
CORPORATION  
BOX 997  
SCHENECTADY, N. Y.

**Try Remler for Service-Tested  
"Hard-to-Get" Components**



## Custom Components

Metal-plastic components designed and manufactured to order. Write for quotations specifying electrical and mechanical characteristics. Describe application. No obligation.

## PLUGS & CONNECTORS

### BANANA PIN TYPES...JAN SPECIFICATIONS

Multi-contact connectors and mating chassis counterparts. Melamine or alkyd insulation; steel or brass nickel-plated shells. Banana springs are heat treated beryllium copper. Unexcelled low resistance contact. Highest quality...good for thousands of connects and disconnects.

**Special Connectors to Order**—Miniatures; water tight and pressure proof types to JAN specifications.

Remler Company Ltd. 2101 Bryant St. San Francisco 10, Calif.

# Remler

Since 1918

PIONEERS IN ELECTRONICS AND PLASTICS

"Made by Engineers for Engineers"



# custom CORD SETS

Available in rubber, neoprene and plastic

Tailored to your needs... quality controlled from start to finish...deadly enemies of CORDelirium! You make the electronic products and we will supply the dependable connecting parts.

Also  
"NOFLAME-COR"  
The Television Hookup Wire

## CORNISH WIRE CO., INC.

50 Church Street. New York 7, N. Y.

**RADIO ENGINEERING  
SHOW**

## Invitation to

4 great days at the  
1952 IRE Convention  
and Radio Engineering  
Show—

214 Engineering Papers  
skillfully grouped in  
30 Technical Sessions  
12 Professional Group  
Symposiums, and  
2 big general meetings.  
356 Product Exhibits, plus  
the IRE Military Radio Ex-  
hibit.

Annual Banquet

Cocktail Party

Presidents' Luncheon.



Where could  
you learn more  
in four days or  
get your procure-  
ment questions  
answered?

The Convention Theme  
"Forty Years Sets the Pace"  
signals the importance of  
IRE's first 40 years (1912-  
52) in pacing the progress  
to come.



Remember  
March 3-6,  
1952  
New York City

Registration  
Members \$1., Non-Members \$3.

**Come and See  
355 Exhibits**

**Radio Engineering Show - March 3-6,  
Grand Central Palace New York City 1952**

# ELECTRONIC ENGINEERS

## Seniors and Juniors

■ Outstanding opportunities for engineers with background in one or more of the following fields:

- Wide Band Video and Low Power Pulse Circuitry, Including Amplifiers, Oscillators, Modulators
- Wide Band FM Circuits
- Microwave Techniques, Incl., Antenna Design, RF, Plumbing and Tubes, Such as Traveling Wave, Klystron, Magnetron

Experience should include design, analysis, and development in above fields.

To work with internationally known scientists in well equipped Manhattan laboratories of leading electronic concern on fundamental research and development problems.

Top compensation for qualified men.

Write full details including salary required to

Director of Research

**FREED RADIO CORP.**

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TELEVISION • RADIO-PHONOGRAPHS

## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 197A)

### Double Pulse Generator

Berkeley Scientific Corp., 2200 Wright Ave., Richmond, Calif., is now marketing a new double pulse generator, Model 903, designed for general laboratory work. It produces either single or double pulses, such that the amplitude and width of each pulse is continuously and individually variable. Spacing between pulses is controlled by means of a calibrated front panel knob.



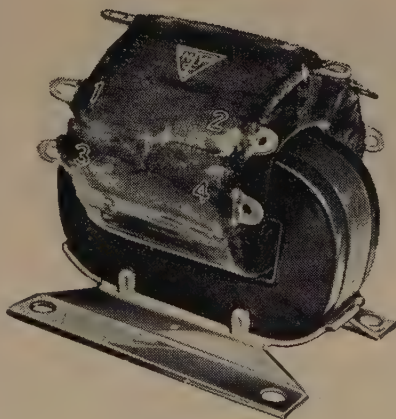
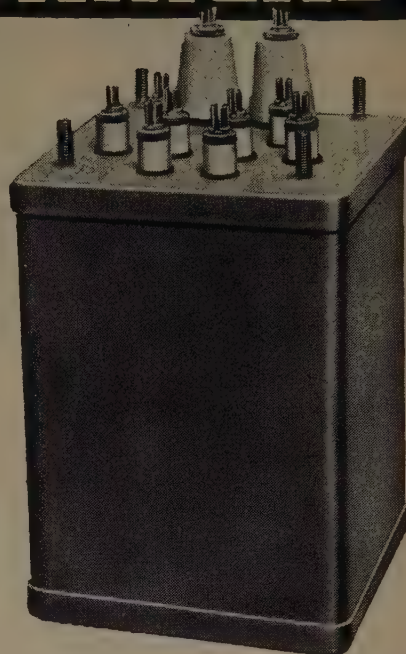
The unit is capable of producing either positive or negative pulses. The amplitude of negative pulses is individually and continuously variable from 200 volts maximum into a 1,000 ohm load, and 10 volts

(Continued on page 201A)

# FULL RANGE OF MIL-T-27 TRANSFORMERS

## HERMETICALLY SEALED UNITS

NYT hermetically sealed transformers are available in all standard sizes to meet MIL-T-27 specifications, and especially designed constructions for a wide variety of military as well as civilian applications. Designed and built to meet the most exacting specifications. Production facilities for quantity production of all sizes.



## the HORNET

HORNET transformers, pioneered by NYT, are of open type construction, utilizing Class H insulating materials. Approximately one-fourth the size and weight of comparable Class A units. Filament and plate supply transformers and chokes. Units can be designed for ambients up to 190 deg. C., altitudes up to 60,000 feet; power ratings from 2VA to 5KVA.

**POWER, AUDIO, FILAMENT  
and PLATE TRANSFORMERS  
REACTORS • FILTERS • CHOKES  
TV • RADIO • ELECTRONICS**



Engineering and development facilities

**NEW YORK  
TRANSFORMER CO., INC.**

ALPHA, NEW JERSEY



See us at the  
RADIO ENGINEERING SHOW  
BOOTH 203



**Standard Piezo**  
**COMPANY**  
CARLISLE, PENNSYLVANIA

## forget CONTROL TEMPERATURE

In addition to lowering power requirements and weight, Standard Piezo's type 20 crystal unit increases compactness, durability and dependability. It meets all Government specifications too.

Standardize on Standard's type 20 and discover how it can cut cost and increase sales for you.

A request on your letterhead will bring engineering data and complete details by return mail.

## Meetings with Exhibits

● As a service both to Members and the industry, we will endeavor to record in this column each month those meetings of IRE, its sections and professional groups, and some closely related groups *which include exhibits*.

△

IRE National Convention &  
Radio Engineering Show  
March 3-6, 1952  
Waldorf-Astoria Hotel and  
Grand Central Palace  
New York City

Spring Technical Conference  
on Television  
April 19, 1952

Cincinnati Engineering Society  
Building, Cincinnati, Ohio  
Adv. & Exhibits: Wynne W. Gulden  
3272 Dayton Avenue  
Cincinnati 11, Ohio

△

NEREM, Saturday, May 10, 1952  
Copley Plaza Hotel, Boston, Mass.

New England Radio  
Engineering Meeting  
Gen. Chairman: Alfred J. Pote  
71 West Squantum St.  
N. Quincy, Mass.

△

National Conference on  
Airborne Electronics  
May 12, 13 & 14, 1952  
Hotel Biltmore, Dayton, Ohio  
Exhibits: Paul D. Hauser  
1430 Gascho Drive, Dayton 3

△

4th Southwestern IRE Conference  
May 16, 17, 1952  
Rice Hotel, Houston, Texas  
Exhibits: Gerald L. K. Miller  
1622 W. Alabama  
Houston 6, Texas

△

Radio Parts Show  
Chicago  
May 19-24, 1952

△

Western Electronic Show and  
IRE Regional Convention  
August 27, 28 & 29, 1952  
Municipal Auditorium  
Exhibits: Heckert Parker  
215 American Avenue  
Long Beach, Calif.

△

National Electronic Conference  
Sept. 29, 30, Oct. 1, 1952  
Hotel Sherman, Chicago, Ill.



MODEL D-2

### PULSE TRAIN CALIBRATOR

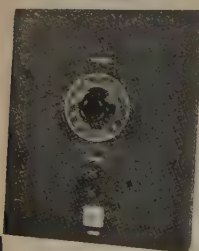
- An accurate, crystal-controlled electronic device for the generation of pulse trains from 10 to 200,000  $\mu$ s spacing.



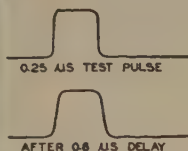
Write for complete data: Our Bulletin I-D-2

**Rutherford ELECTRONICS CO.** 3707 S. ROBERTSON BLVD.  
CULVER CITY, CALIFORNIA

See us at Booth 335



### Type 302 Continuously Variable Delay Line



This is the first commercially available distributed-parameter line capable of providing continuously variable time delay from zero to 0.6 microsecond. Its transmission characteristics are far superior to those of electron-tube delay circuits, ultra-sonic lines, or other delay systems. Pulse response of Type 302 variable delay line may be seen on the left oscillograms. Upper—Waveform of a test pulse having 0.25 microsecond duration. Lower—Waveform of the same pulse after being delayed 0.6 microsecond by Type 302 variable delay line.

#### SPECIFICATIONS

TIME DELAY:  
Continuously variable from 0 to 0.6 microsecond.

RISE TIME:  
 $0.00082 \sqrt{t}$  microsecond, where  $t$  is the amount of delay in millimicrosecond.

CHARACTERISTIC IMPEDANCE:  
960 ohms nominal.

ATTENUATION:  
The attenuation in db per 100 millimicrosecond delay is: approximately zero below 1 mc, 0.3 at 5 mc, 0.95 at 10 mc, 1.3 at 20 mc, and 1.5 at 30 mc.

**ADVANCE ELECTRONICS CO., P. O. Box 394, Passaic, New Jersey**

# News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 199A)

maximum into a 50 ohm load. The amplitude of positive pulses is continuously and individually variable from 50 volts maximum into a 1,000 ohm load and 2.5 volts maximum into a 50 ohm load. Separation of the pulse pairs is continuously variable from 0 to 10 microseconds and can be read directly. The rise time of the pulses is 0.035 microsecond, and decay time less than 0.15 microsecond. Pulse width is individually variable from 0.1 to 1.8 microseconds. The repetition rate of either single pulses or pulse pairs is internally controlled from 1 to 1,000 pulses per second. Single cycle pulses or pulse pairs may be obtained by means of a pushbutton. The unit can be driven from an external generator at any rate up to 1,000 pulses per second.

## Dual Predetermined Counter

The Potter Instrument Co., Inc., 115 Cutter Mill Rd., Great Neck, L. I., N. Y., has announced their manufacture of a new dual predetermined electronic counter which will find greatly increased use where the rate of material flow is extremely rapid. This dual predetermining feature facilitates slowing down in the final stage of a cycle to obtain satisfactory operation of gates, shears and other devices.



The Model 243 dual predetermined counter will continuously recycle, accepting counts up to 1,000 per second, and reset instantaneously after each output operation without missing a single count. The output relay action may be either momentary, adjustable over the range from 0.01 to 0.1 second, or spdt stay-put, alternating positions as each predetermined count is reached.

By dial switch settings any two numbers from 1 to 9,999 may be chosen as the counting points at which control actuation is to occur. A design improvement now eliminates the necessity of computing the complementary numbers; the counter performs this function automatically.

## Horizontal-Deflection Output Transformer

Tube Dept., Radio Corp. of America, 415 S. Fifth St., Harrison, N. J., has developed a new (230T1) horizontal-deflection-output and high-voltage transformer

(Continued on page 202A)



Picture shows Jennings Type VMMC and UCSX in Mackay Transmitter



Type UCSX  
Vacuum Variable  
Capacitor  
10 to 500 MMFD., 10 KV.,  
60 AMPS., R.M.S.



Type UXC  
Vacuum Variable  
Capacitor  
25 to 500 MMFD. at  
25 KV.,  
100 AMPS., R.M.S.



Type UXHC  
Vacuum Variable  
Capacitor  
25 to 150 MMFD. at  
40 KV.,  
100 AMPS., R.M.S.



Type VMC  
Vacuum Variable  
Capacitor  
50 to 1,000 MMFD.  
at 10 & 15 KV.,  
125 AMPS., R.M.S.

Type VMMC  
Vacuum Variable  
Capacitor  
100 to 2,000 MMFD.  
at 10 & 15 KV.,  
125 AMPS., R.M.S.

Write us for information regarding your own Capacitor problem.  
Literature mailed on request.

## JENNINGS VACUUM CAPACITORS IN 7½ KW. 4-26 MEG.

POINT-TO-POINT  
WORLD SERVICE  
TRANSMITTER

Built by  
**MACKAY RADIO  
& TELEGRAPH CO.**

AD NO. 5 OF A SERIES

Another Capacitor  
Problem Solved—

## WIDE RANGE MOTOR TUNING

Simplified by use of

**JENNINGS  
VAC. CAPACITORS**

Mackay Radio, a unit of the American Cable & Radio System, has utilized the Jennings Vacuum Variable Capacitor to make their modern telegraph stations as free from harmonic radiation as possible. The upper left corner of picture shows a Jennings type UCSX-500 in the output of the double Pi network. The lower center is a Jennings type VMMC-2000 which is the coupling for the Pi network. Without these miniature, compact components, trouble-free harmonic rejection circuits would not be feasible. This Transmitter employs Jennings Vacuum Variable Capacitors throughout, with the exception of two small air variables in the multiplier stages.

The Jennings Vacuum Variable Condensers make direct motor tuning, without switching through the full frequency range, possible, as employed in 30 KW Mackay Radio Point-to-Point Transmitters.

# MAXIMUM PERFORMANCE at MINIMUM COST with the *Browning* OSCILLOSYNCHROSCOPES ON-5A ON-5X SYNCHROSCOPE P4-EX



Model P4-EX is designed for applications requiring a triggered sweep, and where the signal levels met do not demand extremely high-gain amplification. Its many outstanding features include:

- Internal trigger, at a repetition rate of 50 to 5000 per second, easily synchronized with an external trigger if desired.
- Output trigger, with the same range of repetition rates, which can be continuously phased to lead or lag the sweep start by a maximum of 500 microseconds

Detailed specifications and performance data available promptly on your request.

These new instruments represent a high level of precision design and versatility of application at remarkably low cost. Major features that are common to all three instruments include:

- Type 5UP cathode-ray tube, operating at an accelerating potential of 2600 volts. P1, P7 and P11 screens are available.
- Sweep writing rate continuously variable from 1.0 to 25,000 microseconds per inch.
- Sweep calibration in microseconds per horizontal scale division, accurate to plus or minus 10%.
- Vertical amplifier flat within 3 db from 5 cycles to 5 megacycles.
- Vertical calibration voltages, at accuracy of plus or minus 5% for Model P4-EX, and plus or minus 10% for Models ON-5A and ON-5X.
- Vertical amplifier input step attenuator.
- CRT cathode connection externally available, for application of blanking or marker pulses.

NET PRICES, F.O.B. Winchester, Massachusetts:

P4-EX ... \$465.00 ON-5A ... \$485.00 ON-5X ... \$535.00

Write today for **FREE BULLETINS** giving detailed specifications and performance data.



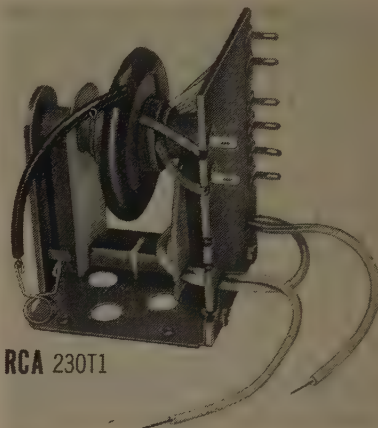
**BROWNING**  
Laboratories, Inc.  
Winchester, Mass.  
ENGINEERED FOR ENGINEERS

See us at Booths S-18, S-19, I.R.E. Show

## News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.  
(Continued from page 201A)

capable of providing a no-load output voltage of 18 kilovolts. It is intended particularly for use with 20-inch and 21-inch picture tubes having a horizontal deflection angle of 66°.



Utilizing a ferrite core, the 230T1 is designed for use with a single, horizontal-deflection amplifier tube 6CD6-G; a single, high-voltage rectifier tube such as the 1B3-GT; and the RCA-211D1 deflecting yoke.

Operation characteristics of the 230T1 make possible the design of a horizontal-deflection system which operates efficiently with a dc power supply of 290 volts, and which provides full deflection of picture tubes having horizontal deflection angles of approximately 66° and operating at zero-load voltages of 18 kilovolts.

## Octave-Band Noise Analyzer

The General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass., announces the Type 1550-A Octave-Band Noise Analyzer which is useful in applications where reasonably continuous spectrum noises are found, and where great detail in the analysis is not required.



Eight pass bands are provided; the lowest is a low-pass filter and the highest a high-pass filter; the middle six, covering from 75-4,800 cps, are each an octave in width. The initial rate of attenuation beyond cut-off of the band pass sections is about 50 db per octave.

An amplifier, a calibrated attenuator, and an indicating meter in the instrument make it possible to measure octave-band levels over a range of about 60 db. A level

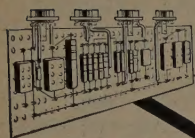
(Continued on page 204A)

## MOVE FROM IDEA TO EQUIPMENT FAST

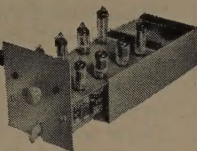
Don't let the component building blocks of new or prototype equipment sap your vital engineering, tooling and manufacturing time. Get the skeleton (chassis), nerve system (cables and connectors), and senses (indicating components) for building your next piece of new equipment to the best standards of modern design from Alden—

### ALDEN BASIC CHASSIS

Circuits organize easily with standard stock components for rapid, easy sub-assembly.



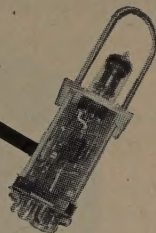
Service and debugging time cut to 30 second changeovers.



### ALDEN "20" PACKAGES



From 17 stock components make 117 plug-in package variations.

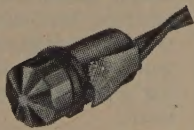


### CONNECTORS AND CABLES

that are designed as units with connectors that use the exclusive Alden top-connected contacts—Leads and contacts are fully insulated in the minimum of space—with minimum of critical material—or even molded into connectors that bond wire and connector insulation into homogeneous unit—so cables and interconnecting devices can be quickly checked, replaced or serviced in the field.

### INDICATING COMPONENTS

Tiny indicating lights with brilliant bulbs that can be changed from front of panel.



Indicating fuseholders that instantly spot blown fuses—yet smaller than standard.

Tiny test points with 6,600 volt breakdown.



See us March 3-6 The IRE Show  
2nd Floor - Booth N-3

Look for the theme, "From Idea to Equipment Fast"—or write for the New Alden Manual "Component Ideas—Techniques—Designs"

**Alden Products Company**

121 North Main Street  
Brockton 64, Massachusetts

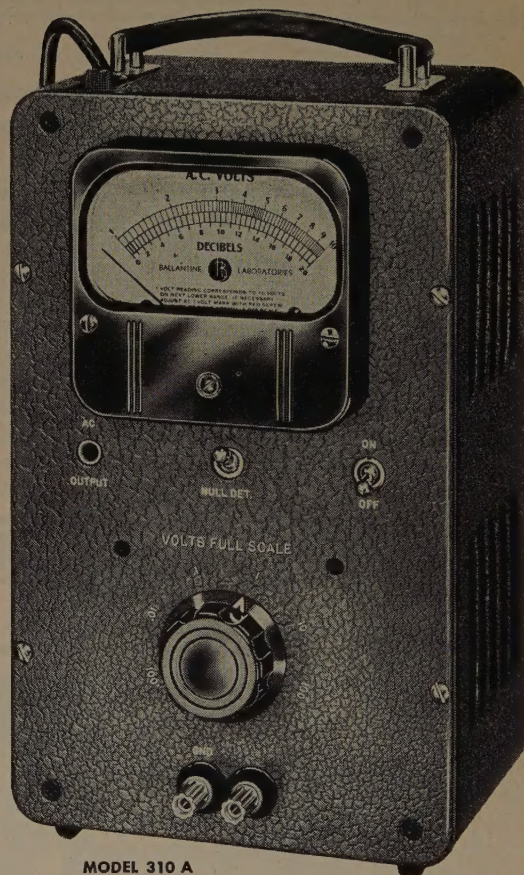
# BALLANTINE

## STILL THE FINEST IN ELECTRONIC VOLTMETERS

Ballantine pioneered circuitry and manufacturing integrity assures the maximum in

### SENSITIVITY ACCURACY STABILITY

- All models have a single easy-to-read logarithmic voltage scale and a uniform DB scale.
- The logarithmic scale assures the same accuracy at all points on the scale.
- Multipliers, decade amplifiers and shunts also available to extend range and usefulness of voltmeters.
- Each model may also be used as a wide-band amplifier.



MODEL 310 A

MODEL	FREQUENCY RANGE	VOLTAGE RANGE	INPUT IMPEDANCE	ACCURACY	PRICE
300	10 to 150,000 cycles	1 millivolt to 100 volts	1/2 meg. shunted by 30 mmfds.	2% up to 100 KC 3% above 100 KC	\$210.
302B Battery Operated	2 to 150,000 cycles	100 microvolts to 100 volts	2 megs. shunted by 8 mmfds. on high ranges and 15 mmfds. on low ranges	3% from 5 to 100,000 cycles; 5% elsewhere	\$225.
304	30 cycles to 5.5 megacycles	1 millivolt to 100 volts except below 5 K C where max. range is 1 volt	1 meg. shunted by 9 mmfds. on low ranges. 4 mmfds. on highest range	3% except 5% for frequencies under 100 cycles and over 3 megacycles and for voltages over 1 volt	\$235.
305	Measures peak values of pulses as short as 3 micro-seconds with a repetition rate as low as 20 per sec. Also measures peak values for sine waves from 10 to 150,000 cps.	1 millivolt to 1000 volts Peak to Peak	Same as Model 302B	3% on sine waves 5% on pulses	\$280.
310A	10 cycles to 2 megacycles	100 microvolts to 100 volts	Same as Model 302B	3% below 1 MC 5% above 1 MC	\$235.

For further information, write for catalog.

**BALLANTINE LABORATORIES, INC.**

102 Fanny Road, Boonton, N.J.



# LIECO

## Announces

### An Improved Waveguide Termination



#### BROADBAND LOW VSWR WAVEGUIDE TERMINATIONS

LIECO NO.	WAVEGUIDE RG-/U	FLANGE UG-/U	USABLE FREQ. BAND KMC/s
16 EB-1	48	53	2.60- 3.95
16 FB-1	49	149A	3.95- 5.85
16 JB-1	52	39	8.20-12.40

Maximum VSWR 1.01 over usable frequency band. Terminations for other guide sizes are in development.

#### A Quality Manufacturer and Development Laboratory ENTERS THE MICROWAVE FIELD

##### FACILITIES

Precision Machine Shop  
Welding, Brazing, Soldering  
Spinning  
Waveguide Bending  
Plating, Electroforming  
Anodizing, Alodizing  
Painting, Spraying  
Engineering

##### FIELD OF INTEREST

Directional Couplers  
Duplexers, Mixers  
Tees, Hybrids  
Bends, Twists, Corners  
Antennas, Reflectors  
Attenuators, Terminations  
Flanges, Adapters  
Waveguide and Coax Assemblies

LERNER INSTRUMENT **LIECO** & ELECTRONIC MFG. CO.

47-49 BERGEN ST., BROOKLYN 2, N.Y.

MAIN 4-1988

## GRANT SLIDING DEVICES

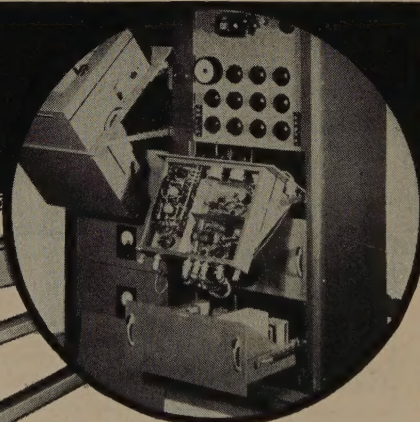
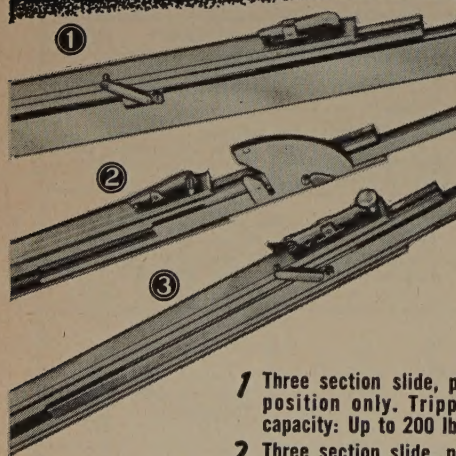


Illustration shows an Automatic Transmission Measuring Set as developed by Bell Telephone Laboratories at Murray Hill, New Jersey.

Panels are suspended on ball-bearing drawer slides and are pivoted to permit the chassis to be inverted for servicing.

- 1 Three section slide, progressive action type. Locks in extended position only. Tripping mechanism controls unlocking. Load capacity: Up to 200 lbs. — Cat. No. 375
- 2 Three section slide, progressive action type. Locks in open and closed positions. Provided with quadrant to allow for tilting to 90 degrees. Load capacity: Up to 200 lbs. — Cat. No. 364
- 3 Three section slide, progressive action type. Locks in extended position only. Thumb release controls unlocking. Load capacity: Up to 200 lbs. maximum. — Cat. No. 371

FURTHER INFORMATION  
WRITE — ELECTRONIC  
ENGINEERING DIVISION



**GRANT PULLEY & HARDWARE CO.**  
31-87 Whitestone Parkway, Flushing, N. Y.

*The foremost name in Sliding Devices*

See Us at Booth No. 462, I.R.E. Show

## News—New Products

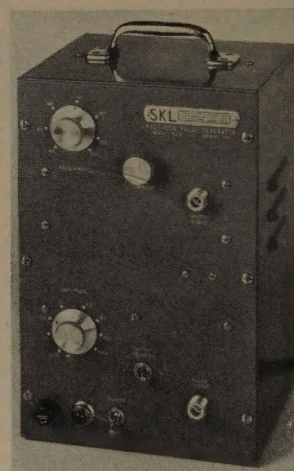
(Continued from page 202A)

control is provided to set the gain of the amplifier, with input levels between 1 to 10 volts.

The octave-band analyzer is designed to operate from the output of a standard sound-level meter, such as the General Radio Type 1551-A and Type 759-B Sound-Level Meter. For levels above 70 db, it can be operated directly from a microphone.

### Pulse Generator

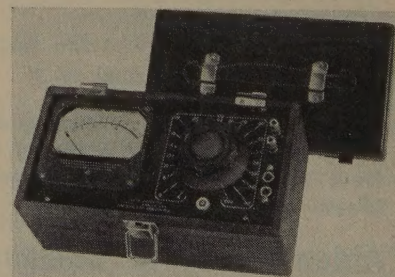
A fast-rise pulse generator is announced by **Spencer-Kennedy Labs, Inc.**, 186 Massachusetts Ave., Cambridge 39, Mass. It produces a rectangular pulse having a rise time less than  $10^9$  seconds. The width of the pulse is controlled by the external "width" cable, and may be as short as  $2 \times 10^9$  seconds. Pulse amplitudes from 0.1 to 100 volts, of either polarity, may be selected. A single pulse, controlled by an external trigger, or internally controlled repetitive pulses, with repetition rates from 50 to 150 per second, may be produced.



The pulse generator is designed for testing the transient response of wide-band systems, but can also be used for the generation of impulse or "continuous spectrum" noise for signal-to-noise ratio testing and for narrow-band receiver alignment.

### Volume Level Indicator

The **Daven Co.**, 191 Central Ave., Newark 4, N. J., announces the availability of its improved Series 911 Volume Level Indicator with components especially mounted to withstand shock and the rough usage given portables.



This unit is completely self-contained,  
(Continued on page 207A)

# PROFESSIONAL CARDS

## TELREX, INC.

M. D. Ercolino, Pres.

H. F. ANTENNA SPECIALISTS

- The Skill to Design
- The Facilities to Produce
- The Ability to Deliver

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## WHEELER LABORATORIES, INC.

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Microwave Components — Test Equipment

Harold A. Wheeler and Engineering Staff

Great Neck, N.Y. Great Neck 2-7806

## New—News Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 204A)

requiring no batteries or external power supply. It is sensitive to low power levels, rugged and dependable.

The indicating meter is a copper-oxide type instrument, possessing ideal characteristics for monitoring purposes. The adjustment is such that the pointer will indicate 99 per cent normal deflection at zero vu in approximately 0.3 second. Overswing is not more than 1 to 1½ per cent. The meter scale is calibrated in vu and per cent.

Two meter controls are provided; one a small decade with screw driver adjustment for zero level setting of the meter pointer; the other a constant impedance "T" type network for extending the range of the instrument in steps of 2 db. These controls make it possible for all vu meters in one installation to be adjusted to the same scale reading when desired.

## ADVERTISER'S INDEX

Starts on page 210A

So many good firms placed advertising in this February Issue that we had to expand our pages after the front index was printed.

See Page 210A



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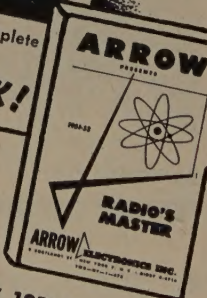
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